SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Infiltration Specifications—Velzy and Sprague

Sand Filter Loadings—Furman et al.

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MARCH, 1955—VOL. 27, No. 3

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28TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

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October 10-13, 1955

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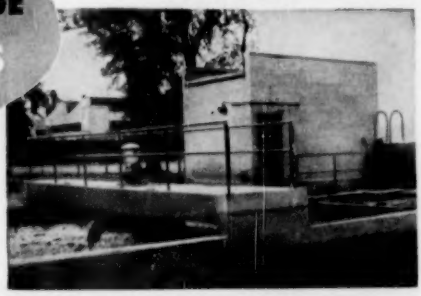

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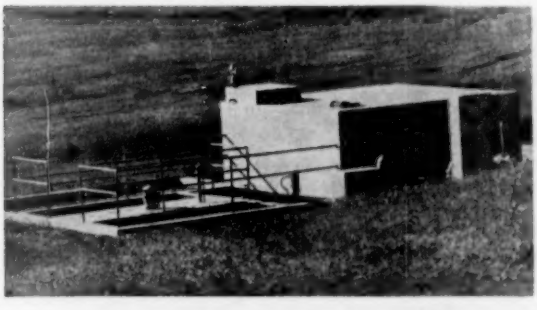

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SEWAGE AND INDUSTRIAL WASTES

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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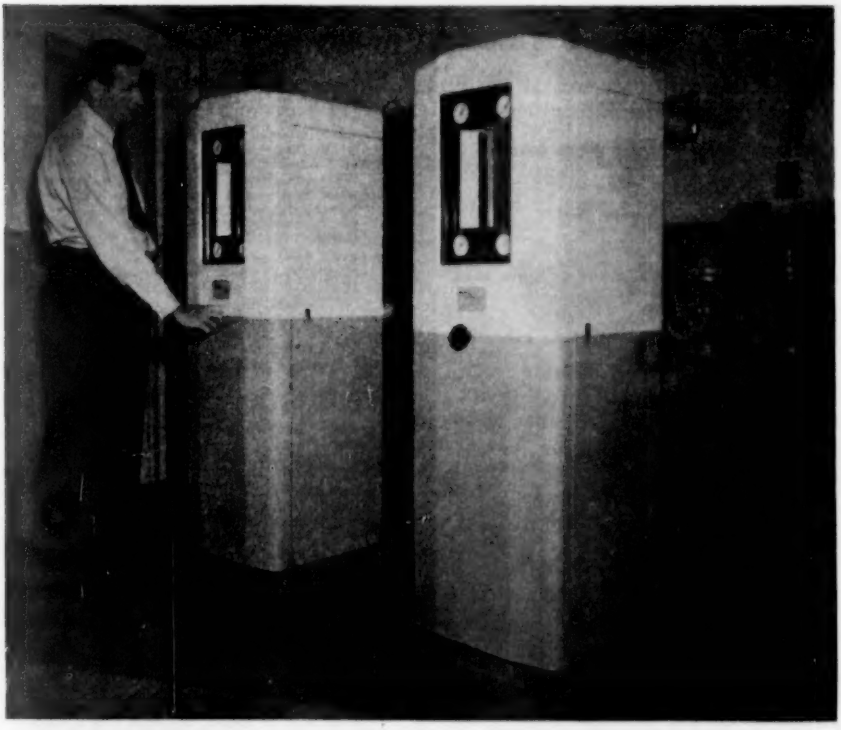

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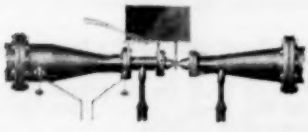

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Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	April 14–16, 1955
California Sewage and Industrial Wastes Assn.	Mission Inn, Riverside, Calif.	April 27–30, 1955
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New York Sewage and Industrial Wastes Assn.	Hotel Ten Eyck, Albany, N. Y.	June 13–14, 1955
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Institute of Sewage Purification	Brighton, England	June 13–17, 1955
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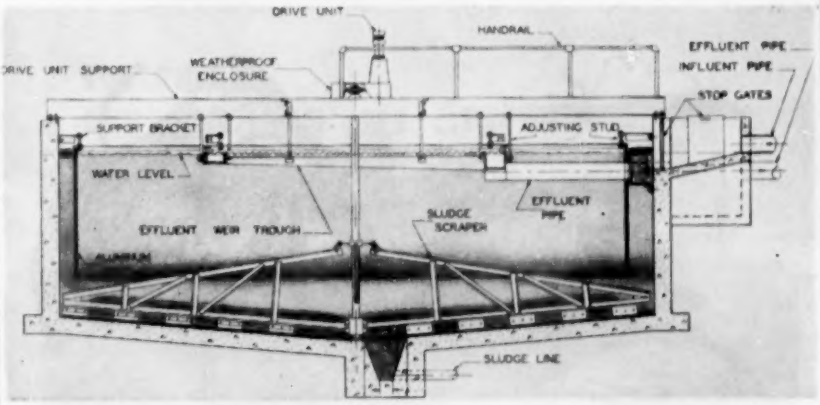

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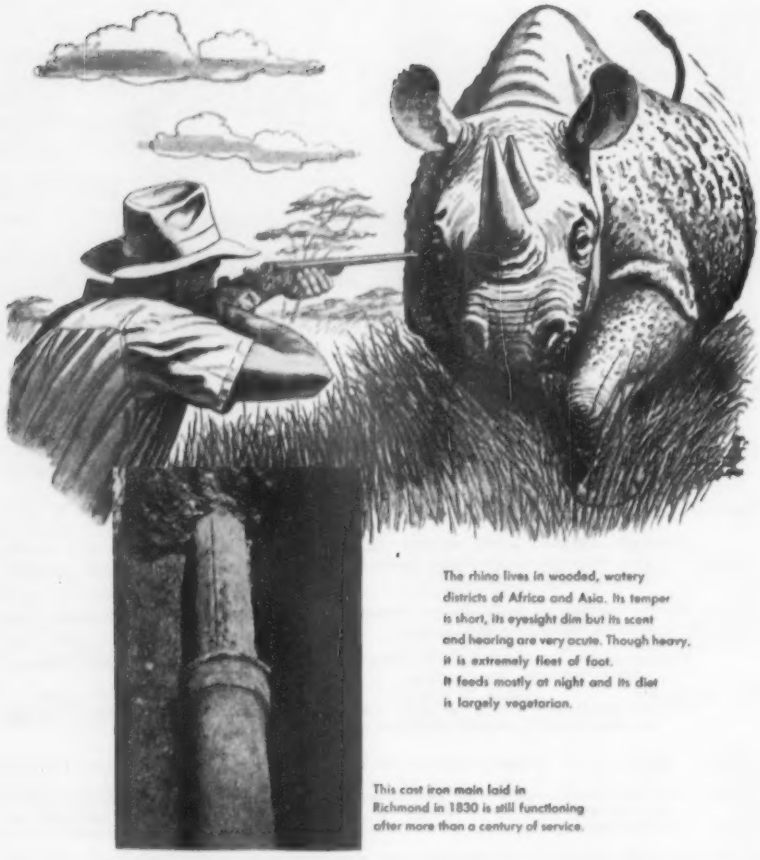

The rhino lives in wooded, watery districts of Africa and Asia. Its temper is short, its eyesight dim but its scent and hearing are very acute. Though heavy, it is extremely fleet of foot. It feeds mostly at night and its diet is largely vegetarian.

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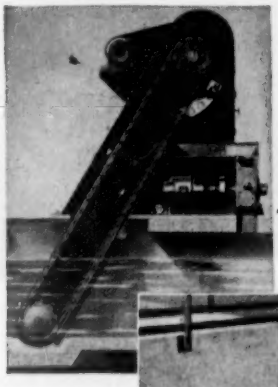

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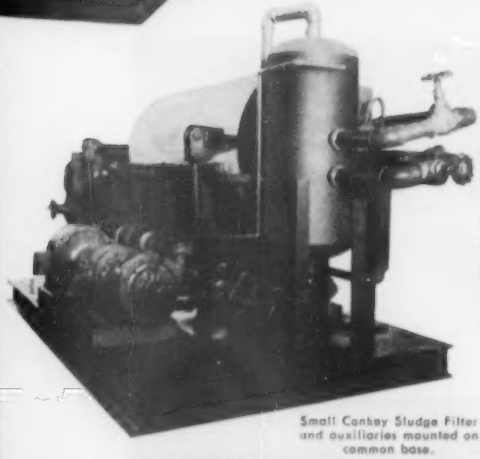
1 or 66

PICK YOUR NUMBER OF FILTERS



Small Conkey Sludge Filter and auxiliaries mounted on common base.

● Conkey Sludge Filters now in use range in size from one filter with auxiliary equipment mounted on a single base (36 square feet of filtering area), to an installation of 66 Rotary Drum Vacuum Filters (38,000 square feet of filtering area), which is the largest rotary type installation ever made for handling sludge.

Municipal and Consulting Engineers have accepted Conkey Sludge Filters as standard dewatering equipment due to their adaptability to successfully dewater many types of sludge and waste.

If you have a sludge or waste disposal problem, write our nearest office and a Conkey Engineer will be happy to work with you.

CHICAGO BRIDGE & IRON COMPANY

Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PA.

CONKEY EQUIPMENT

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston
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Make use of the Unique Advantages of WELSBACH OZONE in Solving Them

The disposal of industrial wastes containing cyanide compounds is always a problem—because they are difficult to treat and must be reduced to very low limits.

That's why you should investigate the potential of Welsbach Ozone in solving these problems. Its efficiency, its economy and above all, its dependability provide an immediate answer. Investigations in the field, as well as laboratory research show that Welsbach Ozone is the ideal solution.

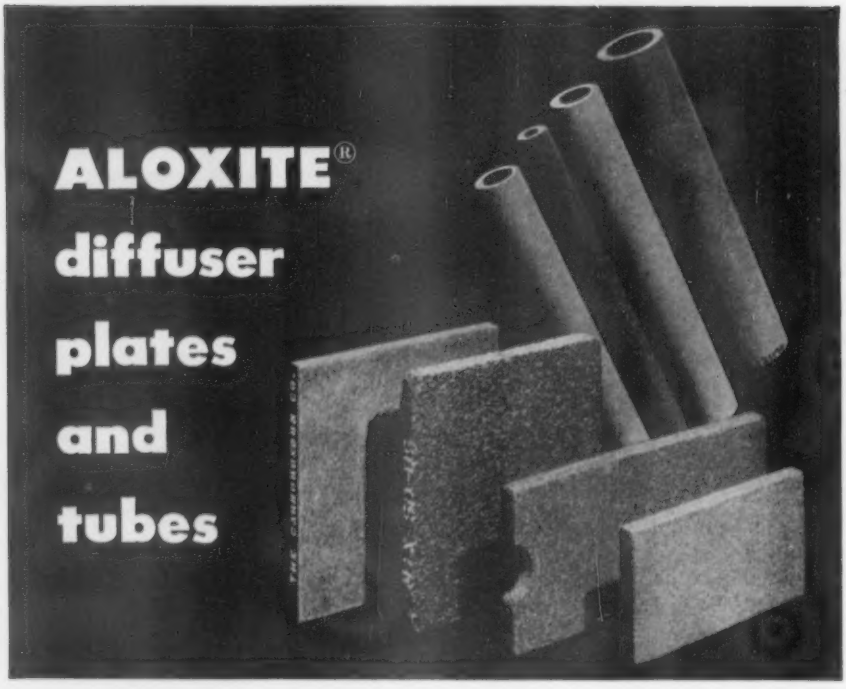
JUST CONSIDER THESE ADVANTAGES:

1. Cyanides are readily oxidized by ozone to products of negligible toxicity.
2. Overdoses of ozone can *not* result in toxic residuals in the treated waste. Therefore, close technical control over dosage is unnecessary and regular maintenance employees can operate the waste treatment plant.
3. Since ozone adds nothing but oxygen to the reaction, re-use or re-cycling of waste waters are often possible, resulting in substantial savings in volume of water used and in waste treatment cost.
4. A Welsbach Ozone plant can be operated on a batch or a continuous basis and can be made fully automatic. Ozonators and treatment vessels require very little space.
5. Welsbach Ozone is generated where it is used. No procurement problems. No freight, storage or materials handling expense.
6. Maintenance costs are negligible. And since the only raw materials needed are electricity and air or oxygen, operating costs are constant and predictable.

. . . but, most of all Welsbach Ozone is economical, convenient and dependable. Write today for information and, if you wish, indicate the nature of your problem. The Welsbach Corporation, Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

Investigate **WELSBACH OZONE**

LOW COST • DEPENDABLE



made from the only TIME-TESTED MATERIAL

When considering air diffusers, these facts are worth keeping in mind: Of the many aeration methods and materials tried since the discovery of the activated sludge process (in 1915), *only one* has stood the test of time. Only porous ceramic diffusers have been used with continued success. And more installations have been made with ALOXITE aluminum oxide diffusers than all makes combined. Hundreds are still operating – many after over 20 years' service.

The inherent advantages of ALOXITE diffusers are: (1) A highly uniform grain structure. This assures uniform, small-bubble diffusion, and, consequently, optimum absorption. (2) A smooth, low-resistance surface. The glass-like ceramic bond that coats each grain minimizes pressure loss or clogging. (3) Permanent resistance to corrosion. (4) Adaptability to practically all cleaning methods. (5) Great strength and ruggedness.

ALOXITE diffusers are available in plate or tube form, and in a full variety of grades. This permits maximum flexibility of design. It also lets you select the exact grade for optimum diffusion, (consistent with air supply quality, pressure loss characteristics, and overall life). This is particularly important since the introduction of the oxygen absorption test.

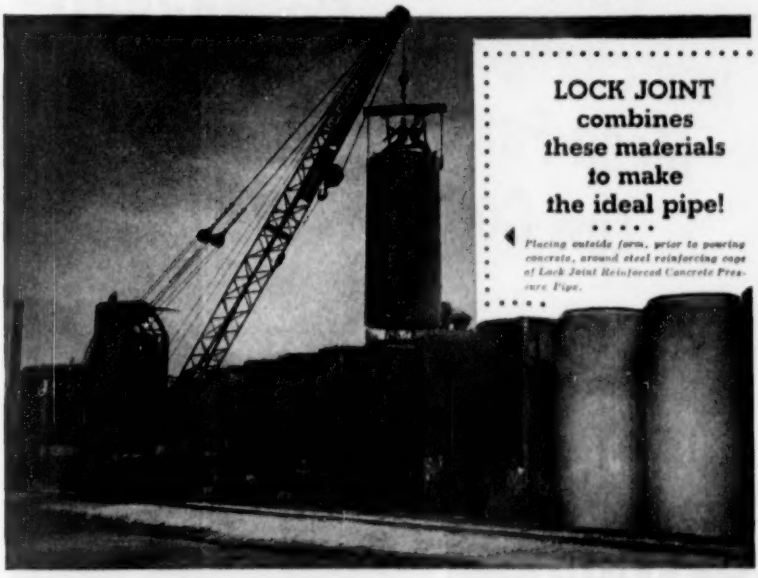
Write for free 56-page booklet.

CARBORUNDUM

Registered Trade Mark

Dept. N-35, Refractories Div. The Carborundum Co., Perth Amboy, N. J.

There's no substitute for CONCRETE and STEEL!



LOCK JOINT combines these materials to make the ideal pipe!

Placing outside form, prior to pouring concrete, around steel reinforcing cage of Lock Joint Reinforced Concrete Pressure Pipe.

CONCRETE, with its proven qualities of durability, non-corrosion, resistance to electrolytic action, and high compression strength is combined, by Lock Joint, with steel's toughness, resilience and high tensile strength to make a pipe that retains the best qualities of both—non tuberculance, high structural strength and long life with little or no maintenance. Dense concrete affords complete protection for the quality reinforcing steel. Both materials are carefully calculated to meet your pressure needs with a wide factor of safety. The Lock Joint Pipe Company's Rubber and Steel Joint is extremely watertight and, at the same time, flexible.

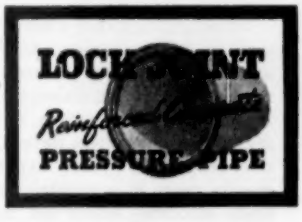
For superior strength, carrying characteristics and trouble-free operation, let Lock Joint supply your pipe needs in sizes 16" and larger.

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, N. J.

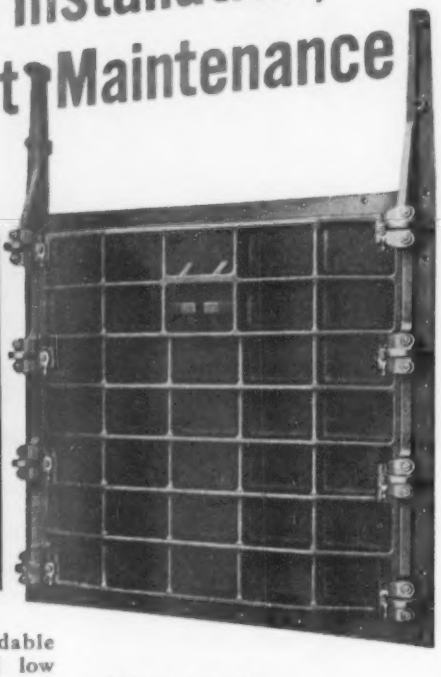
PRESSURE PIPE PLANTS: Wharton, N. J., Turner, Kan., Detroit, Mich., Columbia, S. C.
SEWER & CULVERT PIPE PLANTS:
Casper, Wyo. • Cheyenne, Wyo. • Denver, Col. • Kansas City, Mo. Kennett Square, Pa. • Valley Park, Mo. • Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. • Kenilworth, N. J. • Hartford, Conn. • North Haven, Conn. • Tucumcari, N. Mex. • Oklahoma City, Okla. • Tulsa, Okla. • Beloit, Wis. • Haio Rey, P. R. Ponce, P. R. • Caracas, Venezuela • Wholly Owned Subsidiary, Great Lakes Pipe Co., Plants: Buffalo, N.Y. • W. Henrietta, N.Y.



SCOPE OF SERVICES—*Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains 16" in diameter or larger, as well as Concrete Pipes of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.*

Completely Interchangeable Components Mean Fast Installation, Low-Cost Maintenance

with CHAPMAN *Standard* SLUICE GATES



Fast installation, dependable trouble-free operation and low maintenance costs explain why Chapman *Standard* Sluice Gates are specified everywhere.

Interchangeable components make matchmarking or field alteration unnecessary, so installation is always quick and simple.

Uniform construction, from designs that have been developed in over seventy-five years' experience, means parts fit accurately and operate smoothly under the heaviest unbalanced loads.

Maintenance is simple, too, because repair or replacement parts, when and if needed, are made to the same uniform accuracy for perfect fit without extra work.

Specify Chapman *Standard* Sluice Gates on your job. A wide range of catalogued sizes and designs, all with any type of control you want — manual, electrical, or hydraulic. Write now for Catalog No. 25.

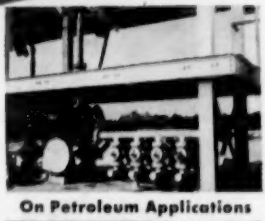
The Chapman Valve Manufacturing Company
INDIAN ORCHARD, MASSACHUSETTS

That's the formula of success behind **acf** Rectangular Port Valves! Because they have a port area at least equal to the pipe itself... turbulence and loss of head pressure are held to a minimum... even when handling heavy slurries and other viscous ladings.

All **acf** *Cylindrical* Lubricated Plug Valves... both those with rectangular and round port openings ...feature split-second, quarter-turn shut off that meets the rigid control requirements in the petroleum, natural gas, and processing industries. Maintenance is especially low because they are fitted with TEFLON* gaskets to prevent head leakage, and have no line seats exposed to fluid flow.

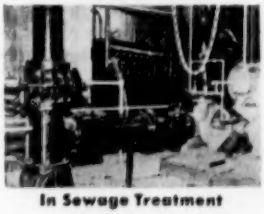
ACT NOW TO KEEP DOWN VALVE MAINTENANCE COSTS!

Representatives in 50 Principal Cities. Write for Descriptive Catalog 5-SI, **acf** Industries, Incorporated, Valve Division, 1501 E. Ferry Ave., Detroit 11, Mich.



On Petroleum Applications

In Chemical Plants



In Sewage Treatment

acf CYLINDRICAL FULL PIPE AREA **PLUG VALVES**

SCREENS:

EASILY FABRICATED OF EVERDUR FOR EXTRA CORROSION RESISTANCE

Fabricated of Everdur® Copper-Silicon Alloys, this sewage screen offers years of protection against corrosion at all stages of sewage treatment. Everdur alloys are the standard for equipment where high corrosion resistance must be incorporated into readily fabricated, lightweight structures.

Everdur applications include gates, guides and bolts, valve and gate stems, weirs, float chambers, troughs, manhole steps and electrical conduit. These highly corrosion-resistant alloys are characterized by great strength and excellent working properties. Depending on which alloy is used, Everdur may be worked hot or cold, welded, machined, forged or cast and is available in plates, sheets, rods, tubes, electrical conduit and casting ingots.

If you would like detailed information for specific applications or designs, the services of our Technical Department are always available to you. Our Publication E-11 describes Everdur Alloys and applications in detail. Write for it. The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

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EVERDUR
ANACONDA®
COPPER-SILICON ALLOYS
STRONG • WELDABLE • WORKABLE
CORROSION-RESISTANT

CLAY PIPE

Sewers and Drains

New CHEVROLET Engineering Center

More than seven miles of Vitrified Clay Pipe, in diameters up to 27-inch, have been installed in the drainage and sanitary systems of Chevrolet's new $20 million Engineering Center near Detroit. Architectural and engineering work was handled by the Argonaut Realty Division of General Motors. Installation was under the supervision of Clay Langston of Bryant & Detweiler Co., general contractors, and Charles McGee Jr., of Holloway & Thompson Construction Co.

In the new Chevrolet Engineering Center, Clay Pipe drainage and sanitary lines have been combined with a privately owned sewage treatment plant to create what might well be called "the industrial waste disposal system of the future." Clay Pipe is the company's assurance of trouble-free service, and the privately owned treatment plant is the community's insurance that industry will continue to be a good neighbor.

For industrial or other construction, where permanency is the watchword, drainage and sanitary lines *must* be down for "keeps." That's why Vitrified Clay Pipe is the universal preference of engineers and contractors. They depend on it because it *never wears out.*

For *permanent* drainage lines and storm sewers—to protect *permanent* construction—always specify Vitrified Clay Pipe. *It's guaranteed for half a century!*

CLAY PIPE FITTINGS SIMPLIFY INSTALLATION

You never have a "patchwork" of materials when you install Vitrified Clay Pipe. This Hub, for example, permits connection of two spigot ends. It's only one of dozens of readily available fittings made of the same never-wear-out Vitrified Clay as the pipe itself.

Vitrified

CLAY PIPE

NEVER WEARS OUT!

NATIONAL CLAY PIPE MANUFACTURERS, INC.

1520 18th St. N.W., Washington 6, D. C.

311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
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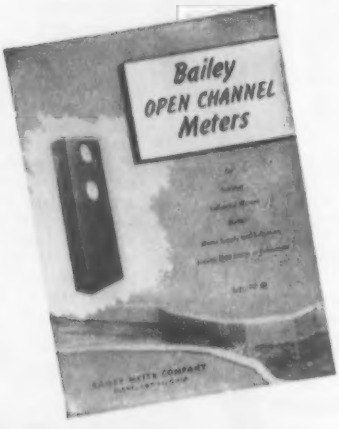
C-355-1A

For trouble-free, low cost measurement of —

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY
OPEN CHANNEL METERS
Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

Ask for Bulletin 62

MU22

BAILEY METER COMPANY

1066 IVANHOE ROAD • CLEVELAND 10, OHIO

METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

Send for *NEW* 28-page guide to LINK-BELT SCREENING EQUIPMENT

- Thru-Clean Screens
- Straightline Screens
- Trash Screens
- Tritor Screens
- Rotary Drum Screens
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- Revolving Disc Screens

If your operations involve removal of solids from water, sewage or industrial waste — Link-Belt's new Book 2587 is important reading for you. It gives complete dimensions and specification data for four types of coarse screens for removing large solids . . . and three types of fine screens for small solids removal. To help determine your exact need, there are tables indicating the proper size unit for various capacities. In addition, Book 2587 contains over 30 photographs of screening installations and outstanding examples of Link-Belt sanitary engineering. Send for your copy now. Clip the coupon at right and mail today.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY
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Please send a copy of New Book 2587 on Link-Belt Screening Equipment.

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S1W

IMPROVE WASTE TREATMENT

with PROVED

American EQUIPMENT

COMPLETE LINE to Meet Your Exact Needs

Including many Exclusive Developments

Utilize our many years of experience in the development and manufacture of municipal and industrial waste treatment equipment. Our staff of engineers is ready to cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

Send for Manual 149—Modern Processes and Equipment for Sewage and Industrial Waste Treatment

BIO-ACTIVATION—exclusive system combines best qualities of trickling filter and activated sludge. *Bulletin 259B.*

MECHANICALLY CLEANED SCREENS AND GRINDER—with intermittent automatic control. *Design data in Technical Supplement MS.*

GRIT CHANNELS—exclusive Camp Chamber design and Regulator permit easy and instant variation in velocity. *Design data in Technical Supplement CR.*

GRIT SETTLERS—with conveyor, elevator, and exclusive Hydrowash unit which removes grease and organic matter from grit. *Bulletin 249B.*

GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors. *Bulletin 260B.*

SEWAGE AND SLUDGE PUMPS—horizontal and vertical pumps in wide range of sizes, capacities and heads—including cutting type primary sludge pumps, enclosed impeller type sewage pumps, single vane impeller type sewage pumps and recirculation pumps. **Send for Bulletins.**

SLUDGE COLLECTORS—for rectangular and circular tanks . . . flight type and helicoid cross conveyors . . . sludge valves. *Bulletin 253B and Technical Supplement TV.*

AERATORS—downflow mechanical air diffusion type provides thorough and adjustable oxygenation and circulation of liquor. *Bulletin 265A.*

JET AERATION—exclusive method produces an unprecedented rate of oxygen absorption. *Bulletin 265A.*

ROTARY DISTRIBUTORS—reaction and positive drive types with exclusive trouble-free oil seal. *Design data in Technical Supplement RD.*

DOWNFLO FLOCCULATION UNIT—for slow mixing and flocculation of chemicals in sewage treatment processes. *Design data in Technical Supplement PF.*

Send for informative bulletins listed above.

Inquiries on new installations or improvements of existing plants will receive prompt attention.

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IN OUR 87th YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

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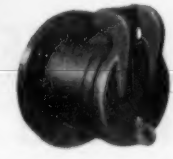
Specify IOWA for every job

Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

Write TODAY for descriptive literature



IOWA FLAP VALVES—all iron; can be furnished with bronze hinge bolts or fully bronze mounted—including bronze bolts, flap ring and seat ring—when required.

CLOW HYDROSTATIC RELIEF VALVES — commonly used in bottom of concrete tanks to prevent ground water from floating the tank. Close-grained cast iron body and lid; lead seat ring and lid ring. Cast iron grate in bottom prevents foreign matter from entering tank.

IOWA PLUG DRAIN VALVES—either rising or non-rising stem type. High strength cast iron bodies; bronze stem, operating nut, disc ring and seat ring; rustproof steel bolts and nuts. Handwheels, extension stems, plain or indicating floor stands if required.

IOWA SLUICE GATES—can be used in lines having both seating and unseating pressures. High strength cast iron, bronze mounted, with solid bronze adjustable wedges. Can be equipped with cylinder or motor unit for automatic operation.

IOWA SHEAR GATES—either all iron or iron, bronze mounted. Gate-seating wedges bolted on, permitting replacement without replacing frame.

For 45 years a reliable source for **precision engineered products**

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for water:
To remove turbidity, color and other impurities

for sewage:
For clarification . . . to floc out suspended colloids and solids—

For sludge . . . to speed drying

GENERAL CHEMICAL "ALUM" is preferred

Here's why water experts and sewage experts alike agree on General Chemical Aluminum Sulfate.

For over 50 years, General Chemical "Alum" has had a reputation for meeting the most rigid chemical and physical specifications of the water and sewage industry. In scores of cities throughout America, public works officials depend on its uniformity and quality.

And, they also depend upon General's coast-to-coast producing and distributing facilities to meet their day-to-day and emergency needs. General has an "alum" supply point near you, too. So, for your operations, specify the *preferred* aluminum sulfate—General Chemical "Alum."

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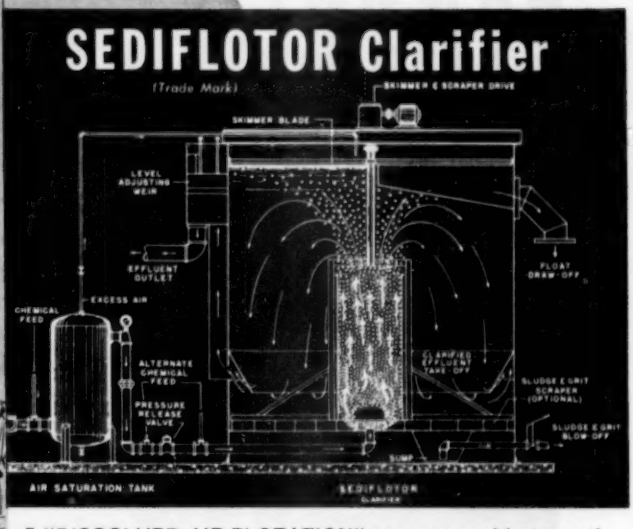
NOW INFILCO ...LEADER IN WASTE-TREATMENT EQUIPMENT ENGINEERING presents the

SEDIFLOTOR Clarifier

(Trade Mark)

—versatile new 2-in-1 waste-water clarification unit



1 "DISSOLVED-AIR FLOTATION" assures rapid removal of suspended material from waste waters.
Here is new efficiency for removing contaminants such as oils, greases, light fibrous materials, etc. Based on the principle of "dissolved-air flotation"— and incorporating reliable chemical feed and operating control, the "SEDIFLOTOR" Clarifier is the answer to many waste problems.

2 GRAVITY-SETTLING CLARIFICATION is included.
"SEDIFLOTOR" Clarifier design also provides the most modern type of gravity-settling equipment, so that both light and heavy materials are removed rapidly and effectively.

Faster...flexible...economical...dependable

Proved by exhaustive test, "SEDIFLOTOR" Clarifier offers marked advantages. The combination of flotation and gravity-settling results in extremely fast and efficient cleansing of waste waters from refineries, packing houses, paper mills, sewage plants (where large amounts of grease and oil are present), chemical and food plants and other similar sources.

It is readily adaptable for use with other equipment, and may be designed for literally any desired flow, with provisions for use of chemical agents, and continuous removal of floating scum and settleable solids.

Quite automatic, the "SEDIFLOTOR" Clarifier operates with maximum economy and requires only periodic attention.

Waste Samples Invited

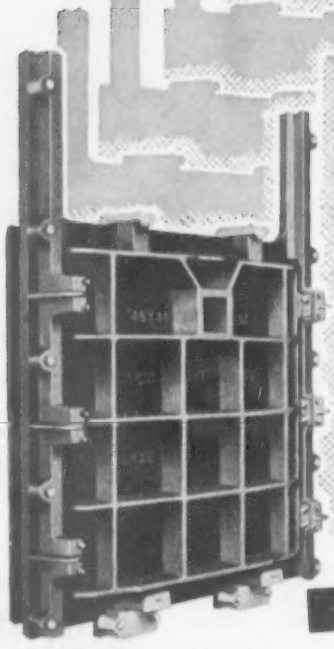
Our laboratory is equipped to test samples of waste water to determine suitable methods and proper size of equipment for your needs. Your inquiry is invited and should include general description of your problem.

INFILCO INC.
921 South Campbell Ave.
Tucson, Arizona
Field offices in principal cities in North America 6830C

INFILCO

The one company offering engineered equipment for all types of water and waste processing—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.

Pekrul Grows



To keep pace with the ever increasing demand for PEKRUL GATES over half a century, MORSE BROS. MACHINERY has just completed an extensive modernization program. The installation of many new machines and facilities, an increased engineering staff, and complete, new, custom re-tooling specifically for PEKRUL GATE production means...

modern design and superior engineering service...

even faster PEKRUL GATE deliveries to you...

PEKRUL GATE DIVISION

MORSE BROS. MACHINERY
DENVER, COLORADO

MANUFACTURERS OF PEKRUL GATES FOR

Flood Control · Sewage Disposal · Roaring Ponds · Recreation Pools
Levees · Reservoirs · Irrigation · Cooling Towers · Pumping Plants
Water Works · Oil Refineries · Steel Mills · Dams · Fish Hatcheries

Why do Armco Sewers get the TOUGH JOBS?

Have you ever wondered why Armco Corrugated Metal Sewers are so often called upon to solve problems involving bad foundations, heavy loadings, joint separation, lining failing structures, aerial sewers, and installation in watery trenches? And why they are so economical, too?

One reason is that Armco Sewers have the advantage of corrugated metal design. They offer a combination of ample strength, flexibility and light weight. Also, in pipe diameters up to 96 inches you can specify the material durability you need—galvanized for normal sewer use, ASBESTOS-BONDED Pipe for severe corrosion, or PAVED-INVERT for erosion hazards.

Installation goes fast with a small crew, holding down labor costs. With Standard Armco Sewer Pipe simple bolted coupling bands join 20-foot lengths; larger MULTI-PLATE Structures are assembled by bolting together pre-curved plates. Both types are supplied in a wide range of sizes. Write for more data. Armco Drainage & Metal Products, Inc., 4495 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

This 27" diameter Armco ASBESTOS-BONDED Sewer helped solve a bad foundation problem in Jeffersonville, Indiana.

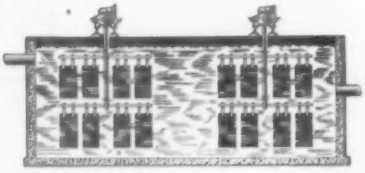
ARMCO®

Armco Sewer Structures

WATER, SEWAGE AND TRADE-WASTE TREATING EQUIPMENT

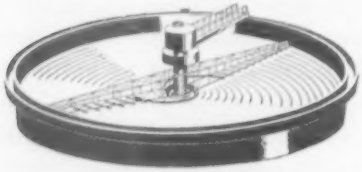
RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. A traveling scraper and skimmer carriage removes settled solids from the tank bottom and scum from the top.



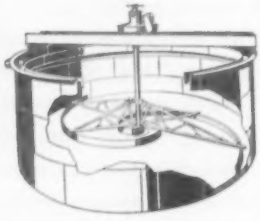
FLOCCULATING UNITS

Slowly rotating paddles on vertical shafts bring the small floc into contact to form larger masses and hasten precipitation.



CIRCULAR CLARIFIERS

Hardinge Circular Clarifiers are available in sizes up to 200' diameter, either center-column or beam supported for steel, concrete, wood or tile tanks. Sludge scrapers remove settled solids rapidly through central underflow discharge.

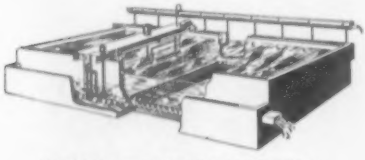


"AUTO-RAISE" THICKENERS

For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage.

HYDRO-CLASSIFIERS

A large-volume classifier for rapid separation of coarse and fine suspended solids. Frequently used for by-product recovery from waste water.



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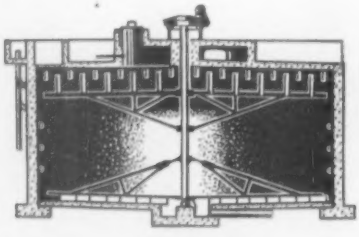

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SEWAGE DISPOSAL PLANT

The new sewage disposal plant in Wyomissing Valley, Pennsylvania (Albright and Friel, Philadelphia, consultants), could have been designed for incineration. But it wasn't. Here's why.

It was known that the sludge would be free from contaminants. By flash drying and selling this sludge, the plant could perform a service to the community and to itself. Dried sludge is rich in humus, is easy to handle and contains the elements found in good topsoil. After being dried, an excellent organic soil conditioner could be made available to the public at a reasonable price. At the same time, the expenses of incineration – ash handling and disposal, for example – would be avoided while the revenue from the sale of the dried sludge would help offset operating expense.

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In communities where the character of the sludge makes it unsuitable for use as a soil conditioner, incineration may be the only answer. But, whether you plan to incinerate or dry, the C-E Raymond Flash Drying System can be designed to allow you to do either at will. Like the communities listed at the right, you too can end your sludge disposal problems effectively and at less cost with the service-proved C-E Raymond System. For full information, contact the C-E Raymond office nearest you. A C-E specialist will be glad to help you. B-810A

WYOMISSING VALLEY
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C-E

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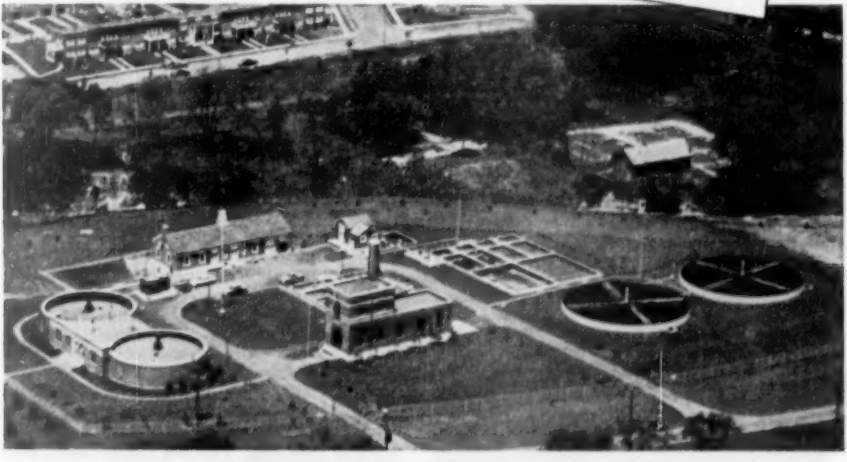
Battle Creek, Michigan	Pri. Dig.	1	6,160	25,000
Chicago, Illinois			7,570	7,550
(Calumet)	Activated			
Southwest	Activated	3	6,667	
Southwest Ext.	Activated	6	21,000	15,850
Edgewater, New Jersey	Pri. Dig.	6	21,000	140,500
Fond Du Lac, Wisconsin	Pri. Dig.	1		49,500
Houston, Texas	Activated	1	195	
Lansing, Michigan	Act. Dig. & Garbage	1	2,310	350
Los Angeles, California	Act. Dig.	2	12,000	1,300
Recife, Brazil	Act. Dig.	1	4,667	30,400
San Diego, California	Pri. Dig.	4		6,700
(1) Plant		1	22,500	79,500
(2) Plant	Pri. Dig.		963	1,300
San Francisco, California	Pri. Dig.	1		
Schenectady, N. Y.	Pri. Dig.	1	7,500	7,500
Sheboygan, Wisconsin	Pri. Dig.	3	5,000	13,200
Stamford, Connecticut	Pri. Dig.	1	6,250	30,400
Washington, D. C.	Pri. Dig.	1	3,570	2,970
	Pri. Dig. New	3	3,040	5,000
	Act. Dig. later	3	3,330	1,700
Wyomissing, Pennsylvania	Pri. Dig.		12,000	65,500
		1	2,210	860



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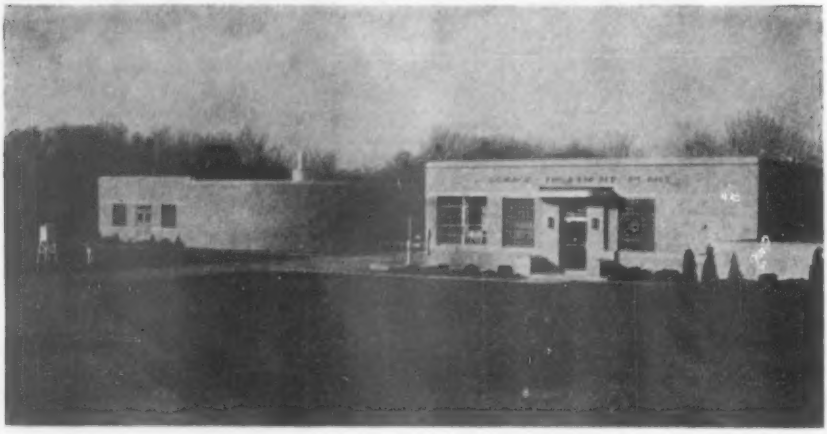

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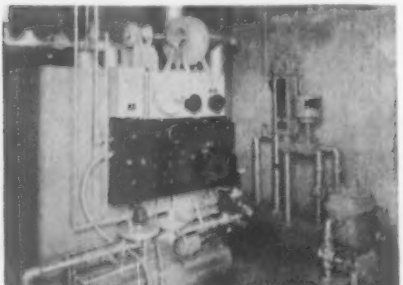

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 27 **March, 1955** **Number 3**

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			Total	Per Unit	Per Unit Per Year	Original Cost	Original Cost Per Year
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Sewage Works

INFILTRATION SPECIFICATIONS AND TESTS*

By Charles R. Velzy and Joshua M. Sprague

Respectively, Partner, Nussbaumer, Clarke & Velzy, Consulting Engineers, New York, N. Y., and Eastern Representative, Clay Sewer Pipe Association, Avon-by-the-Sea, N. J.

The problem of limiting leakage of ground water and storm water into sanitary sewers has become more and more important with the increase of sewage treatment, and the mounting costs of treatment and pumping. With sewage treatment, separate sanitary sewers are being built instead of combined sewers. In sanitary sewers infiltration is important, not only because of the cost of treatment, but also because in the smaller sewer sizes infiltration is a larger proportion of the total capacity and if excessive may require larger pipe diameters.

The limiting of infiltration and the making of a good sewer joint has been a complex problem. There are so many conditions to be met and so many factors involved that the answers are not found in a single research effort, or within the experience of any one individual. Some research has been made, manufacturers have produced various materials, and many engineers have described their experiences, all of which adds to the present knowledge; but there is still need for improvement in materials and methods. There is also a need to determine the reasonable limits of infiltration, and procedures for testing sewers for infiltration. It is probably fair to say that a generally acceptable and completely satisfactory solution to this problem has not been found.

In this treatment of the subject an effort is made to gather some of the existing evidence on what has been done, to make an appraisal of the present status of the problem, and to suggest areas for further work.

The question of infiltration is almost 50 years old. Papers are to be found in the literature dating as far back as 1909 and 1913; after 1920, papers on the subject appear almost every year.

Much information is contained in the papers published in the past, and it is obvious that authors have spent considerable time and thought in gathering data.

As early as 1930 Older and Consoer (1) published results of their studies, which included questionnaire replies by 44 cities. It is interesting to note that 21 of these cities were using asphaltic joints and 14 had specifications limiting infiltration.

In 1946 the results (2) from sending out 500 questionnaires were published. More than one-third of the city engineers who replied indicated that infiltration was a serious problem; in some cases it amounted to from 25 to 50 per cent of the total flow. An interesting comment coming from this study was that an effective joint depends more on workmanship than material.

The characteristics of a good joint in sewer pipe include watertightness, resistance to root penetration, resistance to corrosion, a reasonable degree

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

of flexibility, and durability. These characteristics have a bearing on the amount of infiltration to be expected. In fact, infiltration and quality of joints are so closely related that consideration of one involves the other. It is obvious that a joint which leaks badly is a poor joint regardless of the quality of the materials used, and a sewer line with high infiltration is a line with poor joints. On the other hand, a watertight joint is likely to have the other essential and desirable characteristics.

It is assumed, therefore, that the subject under discussion includes consideration of the various features of sewer joints, as well as the specific question of infiltration.

Leakage of Storm Water

While infiltration relates to leakage of ground water into sewers, some attention also must be given to the entrance of storm water. This may occur through leaking manhole covers or from the connection of roof drains to the sewer.

Rawn (3) described tests made on leakage through manhole covers. The tests indicate that with a depth of 1 in. of water on a cover the leakage may be from 20 to 70 g.p.m., depending on the number and size of holes in the cover. Assuming that 1 mi. of sewer in a residential area serves 600 persons with an average flow of 42 g.p.m., it is apparent that if several manholes along 1 mi. of sewer were to be submerged in this manner, the rate of flow of storm water from this source might exceed by several times the average sanitary flow.

A few roof connections may also contribute excessive flows. Assuming the roof area of a house to be 1,200 sq. ft. and a rainfall of 1 in. in an hour, the flow from one roof would be 750 gal. at the rate of more than 12 g.p.m. Thus several houses connecting downspouts to the sewer within 1 mi. of length could contribute more than the average sanitary flow.

Although the exclusion of storm water from the sanitary sewers is obviously important, it can be accomplished by regulation and ordinance in the one case, and by attention to cover design in the other case. In this problem there are no factors relating directly to the design of the sewer, or which must be provided for at the time of design and construction of the sewer.

Infiltration in Small Sewers is Important

The limiting of infiltration on small sewers is important not only because of the cost and difficulty of repair, but also because in any system the small sizes constitute by far the greater proportion of the total length. This may be illustrated by reference to the system recently designed for the Franklin Square district in Nassau County (Long Island), N. Y. This district has an area of approximately 3,500 acres, has a population of 33,000, and a collection system of about 124 mi. of sewer. Approximately 115 mi., or 93 per cent of this total length is of 8-in. diameter, and an additional 5 per cent is of 10-in. and 12-in. diameter. The maximum size is 24 in. in diameter.

The comments in this paper relate more particularly to the infiltration of ground water into the sewers of 8-in. to 24-in. diameters, because in sizes of 30-in. diameter and larger it is possible to repair joints from the inside. In these smaller sizes satisfactory results must be obtained in the process of laying the sewer, because repair can be made only by the expensive operation of re-excavation, and re-laying or otherwise correcting the faulty work.

Particular attention should also be paid to the quality, installation, and protection of wye branches on sanitary sewers. Reports from Miami, Fla., in 1927 (4) indicate that as much as 30

to 40 per cent of an excessive infiltration observed there was probably due to defective wye branches.

Poorly laid house connections may be another source of infiltration. The importance of tight joints on these connections may be illustrated by reference again to the Nassau County work. On this project the house connections from the sewer to the curb are included in the sewer contracts. In the Franklin Square system the total length of these connections to the curbs is almost one-half the total length of the sewer. When the lines are completed from the curbs to the houses, the total length may be equal to or greater than the total length of the sewers. Thus there is need for good workmanship and inspection on house connections, including the portion placed by plumbers for property owners.

Need for Tight Joints and Infiltration Tests

The rate of infiltration has been expressed in a number of ways. Many of the expressions use the mile as the unit of length and the 24-hr. day as the unit of time. Some relate the rate to diameter of pipe or length of joint, but in the opinion of some engineers the diameter makes little difference in the amount of infiltration. There are so many factors affecting the rate, and test results have been so erratic, that it is difficult to know how much to try to refine the measurements or the expressions for rate of infiltration. It appears reasonable that diameter and total length of joint should have some effect on the amount of infiltration. Thus, if other factors were the same, including materials, workmanship, soil conditions, and ground-water elevation, a 15-in. sewer with almost twice the length of joint as an 8-in. sewer, should show more leakage than the smaller sewer. The rate is usually related to pipe diameter.

In all that has been written on infiltration there are either statements or inferences that it is desirable to reduce to a minimum the rate or amount. A number of reasons have been given and supported by analysis or experience.

One of these reasons is the added cost of pumping and treating the sewage. Horne (5) discusses the question of the cost of infiltration. He states that the cost of pumping and treating sewage at Cranston, R. I., was $14.00 per million gallons, which is in line with costs in other plants of moderate size. He continues that on this basis the cost of infiltration at a rate of 10,000 gal. per mile would be $50 per mile per year. Capitalizing at a 3 per cent interest rate, this represents an investment of $1,667. If tile pipe is used in 3-ft. lengths, this amounts to almost $1 per joint. The difference in cost between a good joint and a poor joint surely should not exceed $1 per joint.

A comparison of infiltration with normal sanitary flow provides another conception of the importance of limiting the rate. It will be assumed that the infiltration in an 8-in. sewer may be 10,000 gal. per mile per 24 hr. This is well within the limits of some specifications and the results obtained in some tests. It amounts to approximately 7 g.p.m. As indicated previously, 1 mi. of sewer in an area well developed with one family houses, may serve 600 persons, with a flow of 42 g.p.m. On this basis the infiltration would amount to about 16 per cent of the quantity of sanitary sewage.

Another reason for insisting on a tight joint is to prevent root penetration. One of the common problems of sewer maintenance is the removal of roots from the lines.

In this connection it may be pointed out that root penetration is more likely to occur in cases where the sewer is above ground water. In such cases, therefore, good joints are still desirable

even though infiltration is not a problem.

Not to be ignored is the possibility that infiltration or imperfect joints may result in washing of sand and silt into the sewer. If severe, this may result in settlement of the street surface or clogging of the sewer. Niles (6) has described how sand and silt gets into sewers from poor joints and causes trouble in sewers, and also in settling tanks and sludge tanks at treatment works.

These various reasons for making tight sewer joints indicate the need for some means of making sure that the desired results are obtained. The test for infiltration or leakage after the sewer is laid, is the method used to meet this need. Inspection alone is not enough. It must be borne in mind that the making of most joints requires certain skills on the part of the man in the trench; the pipe layer is working under adverse conditions and his work is partly invisible. A test after the work is done is, therefore, the only way to determine results.

Fortunately, the leakage test is an indicator of the general character and quality of the finished sewer. First, it shows whether infiltration through joints meets an acceptable minimum. If made after backfilling, it indicates reasonable flexibility in the joint. If a pressure test is used, it indicates satisfactory adhesion of joint material to the pipe. Thus, if infiltration is satisfactory, it is probable the sewer is acceptable.

The need to limit infiltration and to test the sewer when constructed emphasizes the point that the time to build a good sewer is when it is first installed. Poor work at this time can never be completely rectified. To repair joints on a large sewer from the inside is expensive; on small sizes it is impossible. In a few extreme cases sewers have been re-excavated and relaid or otherwise rebuilt.

Specifications

Engineers' specifications usually include two requirements intended to result in good sewer joints and a minmum of infiltration. One requirement limits the type of joint material to be used on vitrified clay pipe, and the other limits the infiltration and provides for a test to prove compliance.

In years past a mortar joint was commonly used. It proved to be too rigid, was subject to cracking, and it was difficult to meet reasonable limits of infiltration with mortar. At present some form of bituminous material is usually specified for vitrified clay pipe.

Of particular interest are the specifications on allowable infiltration, and the tests to measure leakage. On these points there appears to be a lack of uniformity and no generally accepted standards. To get an idea of present thought and practice, inquiries were sent to a number of engineers and cities. The results are given in Table I.

It will be seen that in this group of specifications the limit for 8-in. pipe varies from 1,600 to 12,000 gal. per mile per 24 hr., and for 24-in. pipe from 4,000 to 36,000 gal. per mile per 24 hr., with corresponding variations for the sizes between. It is of interest to note, however, that by far the greater number of specifications are included within the ranges of 3,500 to 5,000 gal. for 8-in. pipe, 4,500 to 6,000 gal. for 12-in. pipe, and 10,000 to 12,000 gal. for 24-in. pipe.

In the answers to the inquiries there were included extracts from specifications and some comments which are of interest. A city engineer states that mortar joints were found to be unsatisfactory but there was good experience with rubber joints. Several cities and consulting engineers indicate that they use hot-poured bituminous joint material. Some require priming of the pipe. One consulting engineer describes in detail the material and

TABLE I.—Infiltration Specifications

Source	Conditions	Allowable Infiltration (gal./mi./24 hr.)				
		Per Inch Diameter	8-In. Pipe	10-In. Pipe	12-In. Pipe	24-In. Pipe
(*a*) Consulting Engineers						
Greeley & Hansen	Average ground	—	5,000	5,000	5,000	5,000
	Wet, perv. ground	—	10,000	10,000	10,000	10,000
Metcalf & Eddy	Average	500	4,000	5,000	6,000	12,000
	Any short section	1,000	8,000	10,000	12,000	24,000
Havens and Emerson	—	500	4,000	5,000	6,000	12,000
Consoer, Townsend & Assoc.	—	200	1,600	2,000	2,400	4,800
Gannett Fleming Corddry & Carpenter	—	500	4,000	5,000	6,000	12,000
William A. Goff	—	—	5,000	6,300	7,500	15,000
Buck, Seifert and Jost	—	—[1]	7,000	8,800	10,500	21,000
Whitman, Requardt & Assoc.	—	250	2,000	2,500	3,000	6,000
O'Brien and Gere	—	—	1,400	1,750	2,100	2,450
John Baffa	Average[2]	—	4,000	5,000	6,000	12,000
Nussbaumer, Clarke & Velzy	—	500	4,000	5,000	6,000	12,000
(*b*) Cities and Districts						
Miami, Fla.	—	1,000	8,000	10,000	12,000	24,000
Milwaukee, Wis.	—	—	5,800	7,250	8,700	17,400
Minneapolis, Minn.	—	—	3,500	3,500	3,500	3,500
Portland, Ore	—	0.5[3]	5,100	6,350	7,600	15,200
Seattle, Wash.	—	—	3,200	3,800	4,400	10,000
Syracuse, N. Y.	—	200	1,600	2,000	2,400	4,800
Tampa, Fla.	—	—	10,000	10,000	10,000	10,000
Tulsa, Okla.	—	—	25,000	—	—	—
Topeka, Kans.	—	1,500	12,000	15,000	18,000	36,000
Stamford, Conn.	—	—	1,160	1,300	1,600	—
Allegheny County (Pa.) San. Auth.	—	150	1,200	1,500	1,800	3,600
Washington (D. C.) Suburban San. Commission	—	—	5,000	6,000	7,000	12,000
Nassau County (N. Y.)	—	0.4[3]	4,000	5,000	6,000	12,000

[1] 2 gal. per foot of joint per 24 hr.
[2] Short sections may be 100 per cent in excess.
[3] Per 100 ft.

method of making various types of joints, including mortar, mastic bituminous, hot-poured bituminous, die-cast or performed bituminous, and rubber gaskets. Another engineer specifies what might be called a composite joint for vitrified clay pipe. The first step is the conventional jute and hot-poured bituminous joint. Outside of this at the end of the bell there is placed a fillet of mortar held in place by a cloth band. Some specifications place one limit on the sewer line or system, and a higher limit on any single section such as the length between any two adjacent manholes. It is apparently customary to apply a leakage test to sewers in dry ground as well as when laid below ground water. Several specifications provide an exfiltration (internal pressure) test when ground water is low or when it is not practical to test under external pressure. Several replies emphasized the need for good workmanship and close inspection.

The Washington Suburban Sanitary

Commission has a particularly interesting requirement in its specifications as follows:

Before any joints are actually made in the trench, the Contractor shall demonstrate to the Engineer, by pouring a sample joint, that the methods he will employ conform with the specifications and will secure a watertight joint, and that the workmen he intends to use in this work are familiar with the requirements.

This provision calls attention to the requirements for tight joints, shows that it can be done and how it will be done, and puts the contractor and the inspector on the alert to maintain good results.

Tests and Measurements

The measurements and tests of leakage in sewers show a range of results from almost perfect watertightness to more than one-half the capacity of the sewer, or to a complete disregard of infiltration. Several large cities, including Boston, Buffalo, Chicago, Detroit, St. Louis, and Cincinnati, have placed no limit on infiltration and have made no tests. Their sewers built in the past have mostly been of the combined type, and infiltration was not a factor.

Some results of measurements are given in Table II, which, of course, is far from complete. For example, the sizes are not given in all cases, and in some cases a range of sizes is given with no indication of the proportion of each size. Where long lengths are given it is possible that not the entire length was tested. There is little information on the nature of the soil or the proportion of the sewer in wet ground. There is nothing on the head of ground water on the sewer and nothing on the methods of testing.

With reservations for lack of data

TABLE II.—Infiltration Measurements

City	Year	Ground Conditions	Joint Type	Sewer Size (in.)	Test Length (mi.)	Leakage (gal./mi./24 hr.)
Boston, Mass.[1]	—	—	—	8 to 36	137	40,000
Canton, Ohio[1]	—	—	—	—	11	26,500
East Orange, N. J.[1]	—	—	—	8 to 24	25	8,650
Westboro, Mass.[1]	1899	—	—	15	0.37	1,320,300
Stamford, Conn.[1]	1892	—	—	6 to 18	13.4	94,170
New Bedford, Mass.[1]	—	—	—	12	—	17,000
Ocean Grove, N. J.[1]	1912	Wet sandy clay	Mortar	4 to 12	6.5	15,000 to 44,000
New York City, N. Y.[1]	—	—	—	8 to 24	5	1,300,000
New Orleans, La.[1]	—	—	—	—	—	45,900
North Shore (Chicago), Ill.	1916	—	Mortar	6	0.2	24,200
South Charleston, W. Va.	1920	Clay, sand, gravel	Mortar	8 to 18	2.60	34,600
Urbana-Champaign, Ill.	1924	Gravel and sandy	Mortar	10 to 18	0.44	18,550
	1924	—	Mortar	12 to 24	1.3	34,400
Miami, Fla.	1926	—	Mortar	—	16.3	1,200 to 7,025
Altoona, Pa.	1930[2]	—	—	8 to 12	2.8	≤6,000
Salt Lake City, Utah	1927	—	Mortar	—	—	39,700
Berlin, Md.	1944[2]	30% wet ground	—	—	8	7%
Harrington, Del.	—	50% wet ground	—	—	8	7%
Florence, N. J.	—	—	—	—	12	20%
Georgetown, Del.	—	—	—	—	8.4	21%
Cranston, R. I.	1945[2]	Low ground water	Bituminous	8 to 39	26.0	<5,500
Glouster, Mass.	1945	High ground water	Bituminous	21	0.18	26,600
Sangus, Mass.	1945	High ground water	Bituminous	8 to 24	3.6	28,200 to 33,500
Webster, Mass.	1945	Low ground water	Mortar	8 to 18	7.5	10,000 to 16,500
Point Pleasant, N. J.	1948	—	Hot pour	8 and 10	1.8	6,000
Lancaster, Pa.	1950	—	Rubber gasket	16 and 18	0.57	8,200 to 9,200
	1950	—	Rubber gasket	18 and 24	1.3	9,200 to negl.
Lemoyne, Pa.	1950	Mostly wet	Hot pour	8 to 20	20	<10,000
Tampa, Fla.	1951	—	—	6 and 8	2.5	1,596
	1952	—	—	6 to 15	5.0	1,800 to 2,700
	1952	—	—	6 to 12	7.1	6,400 to 6,700
	1952	—	—	6 to 21	2.2	7,470 to 8,300
Stamford, Conn.	1953	—	Hot pour	8 to 12	1.0	200
West Elmira, N. Y.	1953	—	Hot pour	8	0.1	3,200
Ewing-Lawrence, N. J.	1953	90% wet	Hot pour	6 to 15	—	3,100
Portsmouth, Va.	1953	—	—	8	0.7	3,400 to 4,600
	1953	—	—	8	0.66	1,100 to 9,900

[1] From reference (9).

[2] Prior to year shown.

TABLE III.—Results of Recent Infiltration Tests on Vitrified Clay Sewers Built in Wet Ground

City or District	Test Length (ft.)	Ground Water Head (ft.)	Joint Type	Infiltration (gal./mi./24 hr.)		
				8-In. Diam.	10-In. Diam.	12-In. Diam.
Stamford, Conn.	5,300 ft.[1]	4	Hot-poured bit.	45	370	280
West Elmira, N. Y.	525 ft.	5	Hot-poured bit.[2]	3,140	—	—
Ewing-Lawrence (N. J.) Sew. Auth.	47+ mi.[3]	—[4]	Hot-poured bit.	3,100	3,900	4,630
Long Beach Township, N. J.	17+ mi.	—[5]	Hot-poured bit.[6]	3,750	4,700	6,000
Point Pleasant, N. J.	9,600 ft.	4+[7]	Hot-poured bit.[8]	5,000	7,050	—
Port Washington, N. Y.	0.5+ mi.	—[9]	Pre-formed bit.	2,600	—	—

[1] Total of three sizes.
[2] With dry oakum gaskets.
[3] 42 mi. 8-in., 5 mi. 10-in., some of larger sizes.
[4] 90 per cent in wet ground.
[5] More than 70 per cent in wet trenches in sand and black muck; trench bottoms stabilized with gravel where necessary.
[6] Jute gaskets.
[7] Salt-water marsh; tested with internal pressure.
[8] Pre-primed.
[9] Trench dewatered with well points; test made after ground water had reached normal level.

on many factors, there are still some observations which can be made. The reports have been arranged chronologically by the year of construction and testing. It will be noted that sewers built 50 years ago show a much higher rate of infiltration than the more recently built sewers. In a 1913 summary (9) of 39 reports, two showed rates of more than 1,000,000 gal. per mile per day; six were between 100,000 and 1,000,000; seven between 50,000 and 100,000; nineteen between 10,000 and 50,000; and five under 10,000. In comparison, tests on sewers laid since about 1938 show rates largely within or better than the ranges of 3,500 to 5,000 gal. per mile per day for 8-in., and up to 10,000 to 12,000 for 24-in. pipe. It appears that progress has been made in obtaining good joints and reducing infiltration.

Table II also shows that in the earlier work mortar was used for joints, whereas on the later work the hot-poured bituminous joint was the prevailing type.

Of particular interest is the information on tests obtained recently from six projects built in wet ground. Details of construction and testing were available. The pipe was vitrified clay in all cases. The results are shown in Table III.

At Stamford, Conn., the test covered some 5,300 ft. of 8-, 10-, and 12-in. pipe with ground water approximately 4 ft. over the top of the pipe when tests were made. Hot-poured bituminous compound was used.

The tests at West Elmira, N. Y., covered 525 ft. of 8-in. pipe tested by internal pressure of about 5 ft. of water. Joints were of hot-poured bituminous compound with dry oakum gaskets.

The Ewing-Lawrence, N. J., project included some 42 mi. of 8-in. sewer, 5 mi. of 10-in. sewer, and some of larger diameter. About 90 per cent of the work was in wet ground. Hot-poured bituminous compound was used. It was stated that infiltration was 44 per cent of the allowable, which amounted to the quantities shown.

Long Beach Township, N. J., lies on Long Beach Island. The sewer system includes more than 17 mi. of sewer and 3 mi. of house connections. Over 70 per cent of the sewers were in wet

trenches, some in sand and some in black muck. Where necessary, trench bottoms were stabilized with gravel. Joints were of hot-poured bituminous compound with jute gaskets. The tests were made after completion of the contract.

At Point Pleasant, N. J., the test covered some 9,600 ft. of 8-and 10-in. sewer laid in a salt-water marsh. Joints were pre-primed hot-poured bituminous compound. The test was made under internal pressure of 4 ft. of water on the upper end of the test section. Of the 34 tests made, some showed leakage of less than 20 per cent of the allowable.

The sewer tested at Port Washington, N. Y., included more than one-half mile of 8-in. pipe laid under ground water, with the trench dewatered with well points. The test was made after construction was completed and the ground water had reached normal level. The joints were of preformed bituminous compound.

These six examples are admittedly specially selected and the results are better than average. They furnish, however, considerable evidence that with good workmanship satisfactory joints can be obtained.

Materials

The material of the pipe is related to infiltration because of the type of joint adaptable to each kind of pipe. The materials commonly used for sewers are vitrified clay, concrete, and asbestos cement. Brick and segmental block have been used in the past, but have fallen into disfavor because of cost and characteristics. Vitrified clay has the longest record of use, and is still an outstanding material for sizes up to 24 in. in diameter. It has competition now from asbestos cement and concrete pipe. In the larger sizes reinforced concrete pipe or monolithic concrete is usually used.

Asbestos cement pipe, because of its smooth surface and regularity of dimensions can use a so-called mechanical joint; a recently developed joint includes a coupling fitted with rubber ring gaskets. It makes up easily, has some flexibility, and meets infiltration limits without difficulty. This joint is made and furnished by the manufacturer of the pipe.

Reinforced concrete pipe has been laid with several different types of joints. Mortar was used in the early years, and bituminous joint material has been used to some extent. In late years the manufacturers of the pipe has been furnishing concrete pipe with forms of rubber gasket joints.

The major problem in obtaining good joints has been with vitrified clay pipe. Because of the relative roughness of joint surface and variance of tolerance in dimension, the type of joint suitable for other pipe would not make a tight joint with tile. The problem with the tile has been of particular importance, also, because such a high proportion of the length of sewer in any system is of the sizes from 8 to 24 in., for which vitrified tile is so commonly used.

As a consciousness developed for a need to limit infiltration and obtain good joints, attention was drawn to the material used for and the methods of making a satisfactory sewer joint. It was found that mortar, which was originally used, had a number of weaknesses; it was too rigid, tended to shrink and crack, was not root-proof, and was subject to damage from water in the trench. In the search for more suitable material, the bituminous joint came into general use.

There are now many types of bituminous joints. In a research on joint material reported in 1947 (7), it was stated that tests were made on 45 compounds. A 1951 list (8) of joint compounds includes 6 sulfur-silica, 7 hot-poured bituminous, and 8 cold bituminous materials for joints. With all the effort on the part of manufacturers to produce a good compound

and the increasing pressure from engineers to get tight joints, there appears to still be room for improvement. Seymour (8) states: "In spite of the many types of joint available and years of developmental work toward the improvement of pipe joints, the perfect sewer pipe joint has yet to be invented."

Perhaps some pertinent considerations and features can be found in past experience with sewer joints. The need for some flexibility in the finished joint has been demonstrated. Experience indicates that it is difficult to be sure of a high degree of skill in the trench. In general, it may be stated that it is possible to get good joints with many of the materials offered, but that without conscientious care and skill almost any material so far used may fail to give satisfactory results. It may be pointed out that care and skill involve not only the manual skill and attitude of the workman, but also the control of features such as temperature of compound, moisture on the pipe, and working conditions.

The presence of these problems with hot-poured and cold plastic bituminous joints, suggests the use of a performed or mechanical joint. Some attempts have been made to furnish such a joint, but little appears to be known regarding the degree of tightness obtained with it.

It is suggested that a successful mechanical joint might be one which has only to be assembled in the trench, requires no special skill to assemble, and is so designed that when assembled it has the essentials of a good joint, including watertightness, flexibility, resistance to corrosion, and resistance to roots. It is encouraging that effort is being made to produce such a joint, and there are probably several designs ready or almost ready to be offered. It is also encouraging that the manufacturers of vitrified tile pipe are working on the problem with the apparent intent of furnishing the joint with the pipe. When pipe and joint material are furnished by different manufacturers there is a divided responsibility which does not help in solving field problems. There is reason to believe that there will be favorable developments in the near future.

Summary

This paper has reviewed some of the past experience with sewer joints and leakage, and has gathered some current thought on reasonable limits of infiltration and how it can be attained. It is suggested that some conclusions can be drawn as follows:

1. Infiltration on sanitary sewers should be kept to a reasonable minimum and tight sewer joints made to avoid the cost of pumping and treating excess flows, to prevent root penetration, and to minimize other maintenance problems and costs.

2. The problem of good joints is important, primarily in small sizes, because such a large proportion of the total length of any system is of small diameter, and because it is so difficult and expensive to correct faulty joints on small pipe.

3. Infiltration tests on sanitary sewers are necessary to obtain low infiltration rates and secure good sewer joints.

4. Tests and measurements of infiltration show an improvement over the years and prove that it is possible, with rubber ring joints on concrete and asbestos cement pipe, and with hot-poured joints on vitrified tile, to obtain acceptable joints.

5. The majority of present opinion appears to favor an infiltration limit represented by the range of 3,500 to 5,000 gal. per mile per 24 hr. for 8-in. pipe.

6. Limited infiltration and tight joints should be obtained in dry as well as wet ground. Measurement in dry ground may be by the internal pressure or exfiltration test.

7. It is emphasized that the time to get a good sewer is at the time of installation. This requires constant attention to workmanship and inspection. There are no short cuts to good sewer construction.

8. Of the many types of joint material for vitrified tile, the hot-poured material appears to have the best record, but none of those commonly used up to the present is perfect.

9. A mechanical joint which needs only to be assembled in the trench has much in its favor, and some of that type may soon be available.

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DISCUSSION

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In their presentation, Messrs. Velzy and Sprague have established the close interrelation between good sewer joints and low infiltration. Whereas good joints are unquestionably the prime requisite for a minimum of infiltration, there are other important considerations which should be taken into account in preparation of an effective specification. It is doubtful that any infiltration specification is fully adequate which does not take cognizance of the various causes of infiltration and seek to establish effective procedures to attain the desired results. It is, therefore, questionable that limiting of the type of joint material and maximum permissible amount of infiltration, with a designated test to prove compliance, constitute within themselves an adequate specification. For example, a sewer may very well meet requirements as to joints and amount of infiltration at time of test, and yet become defective later due to further settlement or excessive trench loading.

Especially pertinent to this discussion, as concerns both specifications and tests, are the recommendations and comments of a committee named by the Sanitary Group, Los Angeles Section, American Society of Civil Engineers. This Committee, made up of engineers, inspectors, contractors, and manufacturers, under the chairmanship of H. W. Jewell, of Pacific Clay Products, was named to study and make recommendations on causes and sources of

infiltration and exfiltration in sanitary sewers.

After spending several months in reviewing literature and engineering manuals, and consulting local authorities, a summary of the causes and sources of infiltration and exfiltration was compiled. This summary, excluding a number of important items not directly related to specifications, gives many good clues as to what to specify in order to minimize infiltration, as follows:

Joints

Poor workmanship.
Poor working conditions.
Inadequate jointing space.
Lack of bond.
Joints not filled.
Cracks in joint material.
Joint material washing out.
Rigid joint material causing broken joint.
Joint material shrinking.

Cracked Pipe

Yielding foundation.
Excessive trench width.
Inadequate laying specifications.
Improper backfilling.
Rigid pipeline.
Settlement of manhole.
Roots.

Defective Pipe

Chemical attack.
Erosion.
Irregular pipe.

Manhole Walls

Poor brick.
Poor mortar.
Poor workmanship.
Lack of plaster on outside walls.
Settlement of manhole foundation.

After making a preliminary report to the Sanitary Group in May 1946, additional data were gathered and the committee, while acknowledging the great magnitude of the problem and the need for further investigations with greater facilities, felt themselves in a position to "point out very salient facts," with the belief that if their recommendations are carried out infiltration and exfiltration can be appreciably reduced. A brief summary of these recommendations, released on February 4, 1947, by the Los Angeles committee, insofar as they have a direct bearing on specifications and tests, is as follows:

1. The designing engineer should avail himself of all pertinent factors pertaining to soil conditions.

2. Designing engineers should accept the premise that all pipelines, regardless of how firm the soil may appear, will, under certain conditions, subside to some extent or shift laterally. Not only is some slight degree of flexibility required in the annular space, but space also should be provided between the abutting ends of the pipe to permit subsidence without placing the pipe under direct shear.

3. Maximum flexibility should be provided at manhole connections by "stubbing" pipes out from each side of a manhole not further than one-half pipe length.

4. Designing engineers should specify flexible joints at branch connections per recommendation No. 2.

5. All house and lateral connections should be laid with joints flexible to the extent of at least one-half the thickness of the annular space.

6. Backfill immediately around the pipe, and for a distance not less than 1 ft. above top of pipe, should be placed by hand and firmly and uniformly compacted without flooding. Where flooding appears economical, careful consideration should be given to the character of the soil adjacent to trench walls to insure wetting will not cause the trench to cave in and subsequently increase the load imposed upon the pipe, and cause the undisturbed area adjacent to the trench to settle and crack.

7. Serious consideration should be given to the uniform practice of ex-

cavating all trenches below the intended subgrade and filling the bottom of the trench with at least 2 in. of pea gravel firmly compacted and brought to uniform grade.

8. All pipes should be laid with a uniform bearing under the full length of the barrel. Suitable bell holes should be excavated in the bedding material and adjustments to line and grade should be made by scraping away or filling in with the bedding material under the pipe barrel and not by wedging or blocking up the bell.

9. After the pipe has been laid and jointed, the backfill should be carried to a point 1 ft. above the top of the pipe and, following a period sufficient to insure proper setting of joints, the line should be tested by an internal hydrostatic pressure equivalent to at least a 4-ft. head of water measured at the lower end of the pipe test section. In general, the infiltration should not exceed 0.6 gal. per minute per inch of diameter per 1,000 ft. of sewer laid in wet ground (4,560 gal. per mile per 24 hr. per inch of diameter.

10. Where hot-poured joints are used, every care should be exercised to insure clean dry pipe, a minimum of caulking, uniform annular space, and properly heated compound.

A discussion of the comments of the committee in substantiation and clarification of their recommendations is beyond the scope of this discussion. It is probably correct to assume that the committee's work presents and inducement for further thought and research, and constitutes an important step in the right direction.

One other point is, perhaps, worthy of a little attention. It may reasonably be assumed that engineers' specifications setting forth maximum permissible infiltration are, in general, predicated more on results currently attainable with vitrified clay pipe, and jointing materials available therefor, than upon the cost of pumping and treating infiltrating ground water. It is possible that under conditions conducive to heavy, continuous infiltration some other piping with fewer and tighter joints might well be justified. Although it is recognized that from economic considerations the use of vitrified clay pipe, especially in the smaller sizes, is normally indicated, it nevertheless remains true that a substantial number of designing engineers and municipalities, under certain adverse conditions, utilize a more watertight piping at a premium in cost. It would seem that the most logical approach to this problem, on the part of the designer, would be an evaluation of the cost of pumping and treating the normally anticipated quantity of infiltration against the cost of armortizing more expensive sewers giving assurance of negligible infiltration.

TENTH EDITION OF "STANDARD METHODS"

WATCH for DETAILS of AVAILABILITY in APRIL issue.

RECENT SEWAGE TREATMENT PLANT COSTS IN IOWA

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Of the 358 cities and towns in Iowa with municipal sanitary sewer systems, only 283 have sewage treatment plants. Most of these treatment plants, constructed between 1920 and 1930 with federal aid grants, are now 25 to 35 years old. Around 50 per cent of the treatment plants need to be enlarged, replaced, or remodeled.

Since most of the cities and towns in Iowa have populations under 10,000, the greatest single obstacle which these small towns face in providing adequate sewage treatment facilities is financing. The most popular financing method at present utilizes a combination of sewer revenue bonds and general obligation bonds. The sewer revenue bonds are retired with money obtained from sewer service charges; the general obligation bonds are retired with money obtained from general taxation. Before a city can give serious consideration to the construction or reconstruction of a sewage treatment plant, a reliable estimate of plant costs must be available for determining the feasibility of financing the improvement. The purpose of this paper is to present a recent survey of Iowa sewage treatment plant costs which may be used in cost estimating.

Most of the treatment plants constructed in Iowa since 1949 have been separate sludge, standard-rate, trickling filter plants. A typical plant of this type includes a lift station and control building combined, a primary clarifier with mechanical sludge collection, a heated digester, sludge beds, a standard-rate trickling filter, and a final clarifier. Some of the final clarifiers have been equipped with mechanical collectors and some with conical or hopper bottoms. All Iowa plants must be designed in accordance with the "Standards for Sewage Works" published by the Upper Mississippi and Great Lakes Boards of Public Health Engineers. The sanitary and functional features of the design must be approved by the Engineering Division of the State Department of Health.

Table I is a list of new municipal sewage treatment plants constructed in Iowa since 1949. These plants are entirely new and do not represent additions or revisions to existing structures. The type of plant and the design unit loadings are given in the table. This information is of value when making a cost comparison between various plants.

Table II shows the cost data for the various plants described in Table I. The projected 1954 replacement cost was computed by using the 1954 *Engineering News-Record* Construction Cost Index and the similar cost index on the date the plant was constructed. The *E N–R* Cost Index used in the calculations was the June 15th index for each year as follows:

1949	474
1950	506
1951	542
1952	561
1953	593
1954	622

It is interesting to note in Table I that the design loadings and type of treatment units are practically the same for all of the installations. This is probably due to the fact that the

TABLE I.—Design Unit Loadings for Several Recently Constructed Iowa Sewage Treatment Plants

No.	City	Lift Station	Primary Tank		Digester		Filter	Final Clarifier		Sludge Beds (sq. ft./cap.)
			Type	Loading (g.p.d./sq. ft.)	Type	Loading (cu. ft./cap.)	Loading (lb./a.-ft./day)	Type	Loading (g.p.d./sq. ft.)	
1	Alta	Yes[1]	Round, mech.	480	Heated	3	500	Round, mech.	480	1
2	Clear Lake	Yes	Round, mech.	605	Heated	3	400	Round, mech.	690	1.25
3	Griswold	Yes	Imhoff	490	Imhoff	3	440	Round, hopper	465	1
4	Grundy Center	Yes	Round, mech.	597	Heated	3.08	362	Round, mech.	597	1.37
5	Laurens	Yes	Round, mech.	532	Heated	3	500	Round, hopper	692	1.13
6	Manchester	Yes	Round, mech.	572	Heated	—	400	Round, mech.	572	Lagoon
7	Maxwell	Yes	Imhoff	360	Imhoff	3.6	392	Round, conical	360	1.2
8	New Sharon	Yes[2]	Round, mech.	382	Cold	5.5	380	Round, conical	382	1.25
9	North English	Yes	Round, conical	550	Cold	6.0	375	Round, conical	502	1.25
10	Onawa	Yes[3]	Round, mech.	520	Heated	3.0	450	Round, mech.	430	1
11	Reinbeck	Yes	Imhoff	635	Imhoff	3.13	443	Round, mech.	613	1.25
12	Rock Rapids	Yes	Round, mech.	472	Heated	3	400	Round, mech.	712	1.25
13	Indianola	None	Round, mech.	510	Heated	3	500	Round, mech.	521	1
14	Jefferson	None	Round, mech.	505	Heated	3	424	Round, mech.	396	1
15	Knoxville	None	Rect., mech.	400	Heated	3	354	Rect., mech.	400	1
16	Williamsburg	None	Rect., mech.	372	Heated	3	380	Rect., mech.	475	1.25

[1] On final.
[2] To filter.
[3] Force to plant.

State Department of Health requires a certain degree of treatment and advocates functional plant design that will facilitate simple operation. Since standard-rate trickling filters are simple to operate and produce uniform results, all of the treatment plants built since 1949 have been of this type.

Figure 1 shows the relation between the size of the Iowa community and the cost of a sewage treatment plant per capita on a population equivalent basis. Since the size of the treatment units, and hence the cost of the plant

TABLE II.—Construction Costs for Several Recently Constructed Iowa Sewage Treatment Plants

No.	City	1950 Pop.	Design Pop. Equiv.	Date Constructed	Cost ($)					
					Total	Per Capita		Projected, 1954		
						1950 Pop.	Pop. Equiv. Basis	Total	Per Capita	Per Capita, Pop. Equiv.
1	Alta	1,350	2,070	1951	100,750	74.50	48.50	115,622	85.6	55.9
2	Clear Lake	4,977	16,000	1954	582,770	117.00	36.40	582,770	116.9	36.4
3	Griswold	1,151	1,420	1952	92,781	80.60	65.30	102,870	89.4	72.4
4	Grundy Center	2,135	2,500	1954	130,000	60.90	52.00	130,000	60.9	52.0
5	Laurens	1,556	2,670	1953	123,100	79.20	46.20	129,121	83.0	48.4
6	Manchester	3,969	5,400	1951	195,946	49.30	36.30	224,870	56.6	41.6
7	Maxwell	802	1,200	1953	57,794	72.10	48.20	60,621	75.6	50.5
8	New Sharon	1,085	1,260	1953	59,226	54.60	47.00	62,123	57.2	49.3
9	North English	853	2,028	1953	115,992	136.00	57.20	121,665	142.6	60.0
10	Onawa	3,488	5,847	1950	191,000	54.80	32.70	234,787	67.3	40.1
11	Reinbeck	1,460	1,854	1953	95,550	65.50	51.60	100,223	68.6	54.0
12	Rock Rapids	2,640	4,400	1953	199,000	75.50	45.30	208,733	79.1	47.4
13	Indianola	5,145	7,100	1953	231,044	45.00	32.60	242,344	47.1	34.1
14	Jefferson	4,324	6,180	1950	167,000	38.70	27.00	205,285	47.5	33.2
15	Knoxville	7,604	9,240	1949	207,817	27.30	22.50	272,705	35.9	29.5
16	Williamsburg	1,183	1,977	1953	81,848	69.10	41.40	85,851	72.6	43.4

itself, is based on the population equivalent, the comparison shown is made on this basis. In some of the communities listed in Tables I and II the industrial loadings equal or exceed the domestic loadings. Curve A (Figure 1) shows the trend of costs for treatment plants that require a lift station at some point within the plant. The majority of lift stations raise the raw sewage from the plant influent to the primary settling tanks. A few plants lift settled or filtered sewage to the following unit. Curve B (Figure 1) shows the per capita cost of treatment plants constructed without lift stations.

To obtain a uniform basis for comparison of the cost data, all of the unit costs were converted to provide a 1954 projected cost. This was deemed necessary because the span of construction of the plants covers six years and the cost of construction varies from year to year. In projecting the *Engineering News-Record* Cost Index at the time of construction to the index on June 15, 1954, a reasonable present-day replacement cost is obtained.

Inspection of Figure 1 indicates that as the design population increases, the unit cost of the treatment plant tends to decrease. This is due to the fact that some items common to sewage treatment plants must be included regardless of plant size. This tends to prove a point that has been known for years.

The unit costs for a complete sewage treatment plant with a lift station will vary in Iowa on the basis of population equivalent. For a town of 1,000 the cost is about $70 per capita. A town of 6,000 can build a plant for about $40 per capita. If no lift station is required, the costs will vary from about $42 per capita for a town of 2,000 population equivalent to about $34 per capita for a town of 6,000.

Since all of the data were for new treatment plants, and not additions or revisions to existing plants, it is believed that Figure 1 can be used in Iowa and nearby states as a guide in preliminary planning for financing a

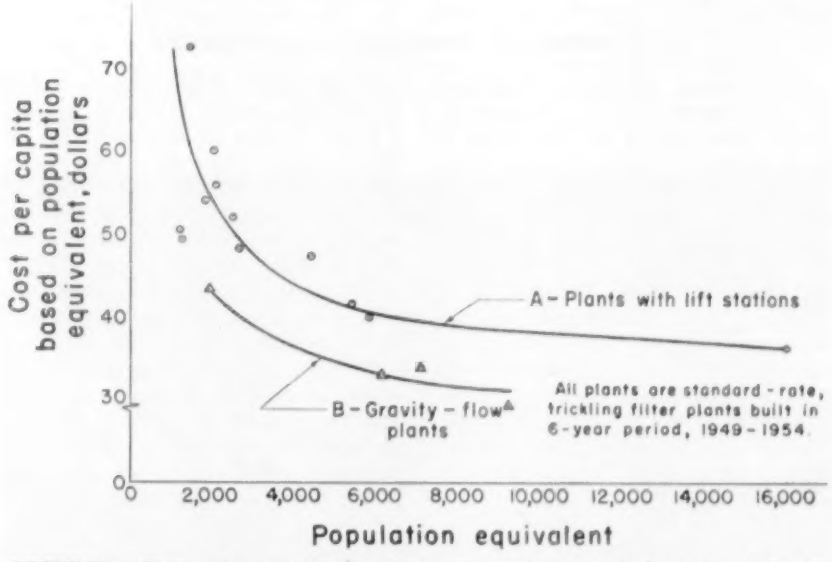

FIGURE 1.—Recent sewage treatment plant construction costs in Iowa, based on the June 1954 *Engineering News-Record* Cost Index (= 622).

new sewage treatment plant. Once a rough estimate of the cost is made, the city or town can arrange its financing to meet the obligation.

The authors recently had an opportunity to make use of Figure 1 for this purpose when they aided in the design of a plant for Belmond, Iowa. Belmond, an Iowa farm community, has a population equivalent of 3,010. In making a preliminary estimate of costs for financing, Figure 1 was used to calculate a probable construction cost of ($47.25 \times 3{,}010$) $142,800. Preliminary financing plans were arranged on this basis. A detailed cost estimate made upon the completion of the detailed plans and specifications indicated a probable construction cost of $139,486. On August 4, 1954, the contract for the construction of the plant was let at a cost of $128,700. Four of the bids received were between $134,691 and $138,148, one was for $151,243 and the high bid was $159,200. The construction cost varied from the cost estimated using Figure 1 by about 11 per cent. The average of the next four bids, $136,221, however, varied from the Figure 1 estimate by only 5.1 per cent. The average of all of the bids, $140,575, varied from the estimate by only 1.7 per cent. It may be concluded, therefore, that Figure 1 may be used to estimate sewage treatment plant construction costs in Iowa with a satisfactory degree of accuracy.

Acknowledgment

The authors wish to express their appreciation to personnel of the Engineering Division, Iowa State Department of Health, for their assistance in making available the data included in this paper.

NON-MEMBER MEETINGS OF INTEREST

The Fourth Southern Municipal and Industrial Waste Conference, jointly sponsored by the University of North Carolina, North Carolina State College, and Duke University, will be held at Duke University on March 31–April 1, 1955. Details may be secured from Department of Civil Engineering, Duke University, Durham, N. C.

Sponsored by the Civil Engineering Department of that institution, a Conference on Biological Waste Treatment is to be held April 13–15, 1955, at Manhattan College. Details from Prof. W. W. Eckenfelder, Civil Engineering Department, Manhattan College, New York 71, N. Y.

United States-Mexico Border Public Health Association will hold its 13th Annual Meeting on May 6–9, 1955, at Mexico City. These dates were chosen to give members the opportunity of also attending the World Health Assembly, to begin in Mexico City on May 10, 1955. Details of the Association meeting are available from Dr. Sidney B. Clark, Pan American Sanitary Bureau, El Paso, Tex.

The 75th Annual Convention of the American Water Works Association will be held June 12–17, 1955, in Chicago, Ill. Details are available through AWWA headquarters, 521 Fifth Ave., New York 17, N. Y.

INTERMITTENT SAND FILTERS—MULTIPLE LOADINGS

By Thomas deS. Furman, Wilson T. Calaway and George R. Grantham

Respectively, Associate Professor of Civil Engineering, Assistant Professor of Sanitary Science, and former Associate Professor of Civil Engineering, University of Florida, Gainesville, Fla.

The use of the intermittent sand filter has, within the past 10 years, experienced a revival in Florida as a method of sewage treatment. This method of treatment is now being widely used throughout the State to provide a high degree of sewage treatment for such isolated installations as motels, trailer parks, drive-in theaters, consolidated schools and small housing developments. In an effort to determine the most effective design criteria loading parameters, and operational procedures under local conditions, the Sanitary Research Laboratory (1) (2) (3) of the Engineering and Industrial Experiment Station, University of Florida, is making a study of this method of treatment. Part I of this work (4), initiated in 1944, was an investigation of native Florida sands to determine which were adaptable to this method of treatment. Grantham *et al.* (5) reported on Part II, which dealt with a pilot-plant study of sand filters, loaded once each day, at various hydraulic loading rates. This report covers Part III and is a study of sand filters at various hydraulic loading rates when the sewage is applied more frequently than once each day.

Description of Units

When the Sanitary Research Laboratory was completed in 1947 eight sand beds were provided for actual pilot-plant study (Figure 1). These filters are 7.4 ft. square (1/800 acre). The walls are of reinforced concrete 4.5 ft. high and the bottoms are either asphalt-bound limerock (Filters 8, 9, 10

FIGURE 1.—Experimental filters used in intermittent sand filter studies.

TABLE I.—Characteristics of Sands in Experimental Filters

Filter No.[1]	Sand		
	Effective Size (mm.)	Unif. Coef.	Depth (in.)
8	0.46	2.79	30
9	0.25	2.22	18
10	0.25	2.24	30
11	0.44	2.78	18
12	0.31	3.26	30
14	1.04	1.70	30
15	0.29	3.27	18

[1] Filter No. 13 was converted into a contact bed and not used in this sand filter work.

and 11) or concrete (Filters 12, 13, 14 and 15). The bottom of each bed is covered with 6 in. of graded gravel and filled to a specified depth with sand of a uniform size and character (see Table I).

The majority of the sewage entering the pilot plant comes from a veteran student housing project located on the campus. This village contains 78 units and provides housing for approximately 300. The difference between the village flow and the 65 g.p.m. required for plant operation is made up from the trunk sewer of the campus proper.

On entering the pilot plant the sewage passes through a mechanically cleaned bar screen with ¾-in. clear openings. The screenings are added to the main sewer which leads to the campus plant. The sewage is then pumped to a distribution box where the flow is divided and portions channeled into a primary sedimentation tank and an Imhoff tank. Both units have a theoretical detention time of 2 hr. at a flow of 20 g.p.m. The settled sewage then flows by gravity to a holding and measuring tank until sufficient volume is obtained to dose all beds. Before each loading the tank is thoroughly mixed to insure a uniform sewage and each bed is loaded at a predetermined rate. The volume of the sewage being applied is measured by a calibrated piezometer tube on the side of the tank. After passage through the bed the sewage flows by gravity to the chlorine contact cham-

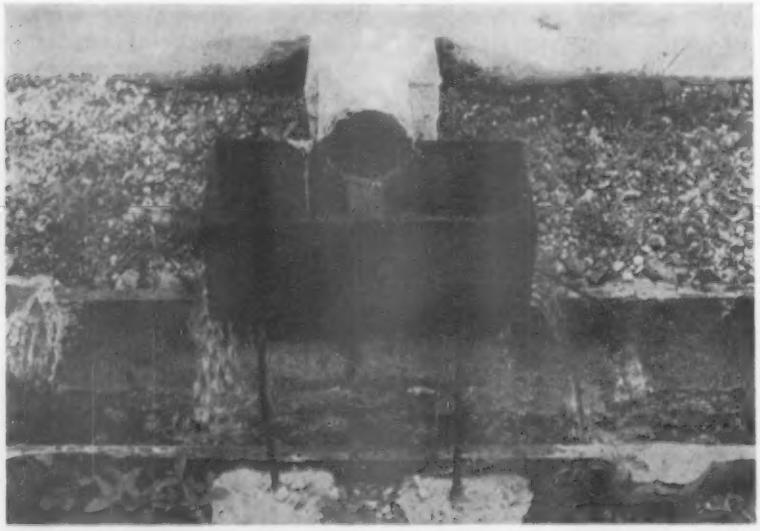

FIGURE 2.—Effluent sampling box. Note tube to right of box for delivering a small portion of the total flow directly to the sample bottle.

TABLE II.—Test Data for Unit 8; Sand Size, 0.46 mm.; Bed Depth, 30 in.

Loading (1,000 g.p.a.d.)	125	150	175	200	225	250	300	325
No. of samples	7	29	8	35	14	18	36	10
B.O.D. infl. (p.p.m.)	142	174	143	96	106	87	121	152
B.O.D. infl. (lb./a./day)	148	217	208	160	198	181	299	412
B.O.D. effl. (p.p.m.)	13	24	28	17	15	15	19	14
B.O.D. removal (%)	90.8	86.2	80.4	82.3	85.8	82.8	84.3	90.8
S. sol. infl. (p.p.m.)	87	106	86	—	—	—	—	—
S. sol. effl. (p.p.m.)	6	20	14	—	—	—	—	—
S. sol. removal (%)	93.1	81.5	83.7	—	—	—	—	—
N infl. org. (p.p.m.)	19.6	18.6	15.2	7.6	6.1	8.5	10.8	12.8
N infl. NH_3 (p.p.m.)	16.9	17.1	19.0	20.3	24.4	17.9	19.4	17.3
N infl. NO_2 (p.p.m.)	0.058	0.002	0.003	0.003	0.007	0.016	0.037	0.021
N infl. NO_3 (p.p.m.)	0.13	0.20	0.59	0.09	0.11	0.20	0.22	0.05
N infl. total (p.p.m.)	36.688	35.902	34.793	27.993	30.617	26.616	30.457	30.171
N effl. org. (p.p.m.)	3.07	4.21	3.06	2.93	2.75	1.74	5.12	3.97
N effl. NH_3 (p.p.m.)	4.26	4.58	5.44	3.19	2.46	3.41	4.88	3.23
N effl. NO_2 (p.p.m.)	0.022	0.062	0.016	0.004	0.005	0.012	0.029	0.015
N effl. NO_3 (p.p.m.)	27.34	18.11	24.84	18.87	25.46	22.70	17.51	18.15
N effl. total (p.p.m.)	34.692	26.962	33.356	24.994	30.675	27.862	27.539	25.365
N oxidized (%)	78.8	67.3	74.5	75.5	83.0	81.5	63.6	71.6
Air temp., av. (° F.)	75	70	72	71	65	71	65	69
Test period	4/5/48–7/23/48	7/24/48–2/12/49	2/13/49–7/7/49	7/8/49–1/12/50	1/13/50–3/26/50	3/27/50–7/13/50	7/14/50–2/9/51	2/10/51–4/8/51

TABLE III.—Test Data for Unit 9; Sand Size, 0.25 mm.; Bed Depth, 18 in.

Loading (1,000 g.p.a.d.)	100	150	175	200	225	250	300
No. of samples	7	17	8	35	15	17	33
B.O.D. infl. (p.p.m.)	142	161	143	96	106	85	123
B.O.D. infl. (lb./a./day)	118	201	208	160	198	177	307
B.O.D. effl. (p.p.m.)	3	3	2	3	3	3	5
B.O.D. removal (%)	97.9	98.1	98.6	96.9	97.2	96.5	95.9
S. sol. infl. (p.p.m.)	87	105	86	—	—	—	—
S. sol. effl. (p.p.m.)	3	8	6	—	—	—	—
S. sol. removal (%)	96.5	92.4	93.0	—	—	—	—
N infl. org. (p.p.m.)	19.6	18.6	15.2	7.6	6.3	8.5	11.4
N infl. NH_3 (p.p.m.)	16.9	17.1	19.0	20.3	24.4	17.9	19.6
N infl. NO_2 (p.p.m.)	0.058	0.002	0.003	0.003	0.008	0.016	0.037
N infl. NO_3 (p.p.m.)	0.13	0.20	0.59	0.09	0.10	0.20	0.18
N infl. total (p.p.m.)	36.688	35.902	34.793	27.993	30.808	26.616	31.217
N effl. org. (p.p.m.)	0.82	1.29	1.71	1.20	1.25	3.31	4.70
N effl. NH_3 (p.p.m.)	1.18	1.21	2.91	3.50	2.78	1.26	4.72
N effl. NO_2 (p.p.m.)	0.010	0.004	0.002	0.003	0.007	0.010	0.063
N effl. NO_3 (p.p.m.)	32.42	19.31	24.06	14.58	15.44	19.35	16.41
N effl. total (p.p.m.)	34.430	21.814	28.682	19.283	19.477	23.740	25.893
N oxidized (%)	94.37	88.53	83.93	75.62	79.42	81.54	63.56
Air temp., av. (° F.)	75	72	72	71	65	70	66
Test period	4/5/48–7/24/48	8/7/48–2/12/49	2/24/49–7/7/49	7/8/49–1/12/50	1/13/50–3/25/50	3/26/50–7/12/50	7/14/50–2/4/51

ber and is then discharged into a small stream flowing past the plant.

Samples of the applied sewage were taken from the influent channel during actual loading; effluent samples were obtained from a sampling box (Figure 2). This device was designed to minimize the error of a grab sample and was so constructed that it delivered a small portion of the flow directly to the sample bottle. Samples were taken approximately every five days. Determinations were made according to the procedures set forth in "Standard Methods" (6). The hydraulic loading was applied in two equal doses, the first at 9:00 AM and the second at 3:00 PM and increased periodically until hydraulic failure of the beds resulted. This phase of the study was initiated in March 1948 and terminated in July 1951. Tables II through VIII present the results obtained.

In January 1951, at loading rates of 300,000 g.p.a.d., units 9, 10, 11, 12 and 15 began to clog. The disappearance time (the time required for the sewage to disappear below the surface of the bed) increased until the sewage of the preceding loading was still covering the surface of the bed at the time of the next loading. When this occurred the bed was considered to have failed. It was then removed from service and allowed to rest for several days (4 to 10, depending on the weather), after which it was put back into operation. When the bed clogged again to the point of failure it was removed from service.

Filters 9 and 12 were discontinued February 4, 1951; filter 15 on February 6; filter 10 on February 7, and filter 11 on February 11.

Filters 8 and 14 did not clog suffi-

TABLE IV.—Test Data for Unit 10; Sand Size, 0.25 mm.; Bed Depth, 30 in.

Loading (1,000 g.p.a.d.)		100	150	175	200	225	250	300
No. of samples		7	17	8	35	14	16	34
B.O.D.	infl. (p.p.m.)	142	161	143	96	106	85	122
	infl. (lb./a./day)	118	201	208	160	198	177	302
	effl. (p.p.m.)	2	3	3	3	2	2	3
	removal (%)	98.6	98.1	97.9	96.9	98.1	97.6	97.5
S. sol.	infl. (p.p.m.)	87	105	86	—	—	—	—
	effl. (p.p.m.)	4	9	10	—	—	—	—
	removal (%)	95.4	91.4	88.4	—	—	—	—
N infl.	org. (p.p.m.)	19.6	18.6	15.2	7.6	6.1	9.2	10.7
	NH_3 (p.p.m.)	16.9	17.1	19.0	20.3	24.4	19.5	19.5
	NO_2 (p.p.m.)	0.058	0.002	0.003	0.003	0.007	0.019	0.037
	NO_3 (p.p.m.)	0.13	0.20	0.59	0.09	0.11	0.20	0.22
	total (p.p.m.)	36.688	35.902	34.793	27.993	30.617	28.919	30.457
N effl.	org. (p.p.m.)	3.90	1.03	1.70	1.98	9.21	2.71	3.25
	NH_3 (p.p.m.)	0.82	1.16	2.71	2.57	1.66	2.00	2.20
	NO_2 (p.p.m.)	0.017	0.018	0.001	0.002	0.005	0.006	0.037
	NO_3 (p.p.m.)	33.4	20.8	24.56	15.09	22.58	23.13	15.48
	total (p.p.m.)	38.137	23.008	28.971	19.642	33.455	27.846	20.967
N oxidized (%)		87.61	90.45	84.77	76.90	67.50	83.08	73.95
Air temp., av. (° F.)		75	72	72	71	65	72	66
Test period		4/5/48–7/24/48	8/7/48–2/12/49	2/13/49–7/7/49	7/8/49–1/12/50	1/13/50–3/26/50	3/27/50–7/12/50	7/13/50–2/7/51

TABLE V.—Test Data for Unit 11; Sand Size, 0.44 mm.; Bed Depth, 18 in.

Loading (1,000 g.p.a.d.)			125	150	175	200	225	250	300
No. of samples			8	17	8	34	14	14	36
B.O.D.	infl. (p.p.m.)		138	160	143	99	106	85	124
	infl. (lb./a./day)		144	200	208	165	198	177	310
	effl. (p.p.m.)		10	30	14	19	22	10	12
	removal (%)		92.8	81.2	90.2	80.8	79.2	88.2	90.3
S. sol.	infl. (p.p.m.)		85	106	86	—	—	—	—
	effl. (p.p.m.)		9	26	11	—	—	—	—
	removal (%)		89.4	75.5	87.2	—	—	—	—
N	infl.	org. (p.p.m.)	19.3	18.6	15.2	7.7	6.1	8.5	10.8
		NH_3 (p.p.m.)	16.3	17.1	19.0	20.7	24.4	17.9	19.1
		NO_2 (p.p.m.)	0.007	0.002	0.003	0.003	0.007	0.016	0.037
		NO_3 (p.p.m.)	0.14	0.20	0.59	0.09	0.11	0.20	0.22
		total (p.p.m.)	35.747	35.902	34.793	28.493	30.617	26.616	30.157
	effl.	org. (p.p.m.)	3.28	6.03	3.03	2.86	1.94	3.15	5.96
		NH_3 (p.p.m.)	6.20	5.82	4.62	5.12	5.49	5.05	5.14
		NO_2 (p.p.m.)	0.016	0.069	0.004	0.003	0.010	0.028	0.034
		NO_3 (p.p.m.)	20.85	13.96	18.50	14.84	17.22	17.63	14.31
		total (p.p.m.)	30.346	25.879	26.154	22.823	24.660	25.858	25.444
	oxidized (%)		68.74	54.14	70.74	65.03	70.13	68.26	56.32
Air temp., av. (° F.)			74	72	72	71	65	71	65
Test period			3/16/48–7/23/48	7/24/48–2/12/49	2/13/49–7/7/49	7/8/49–1/12/50	1/13/50–3/26/50	3/27/50–7/12/50	7/13/50–2/10/51

ciently under this study to be removed from service and were operating satisfactorily when the study was terminated.

It was noticed that while the beds were clogged to the point of hydraulic failure, the degree of treatment afforded to the effluent passing through the bed was still in the neighborhood of 90 to 95 per cent.

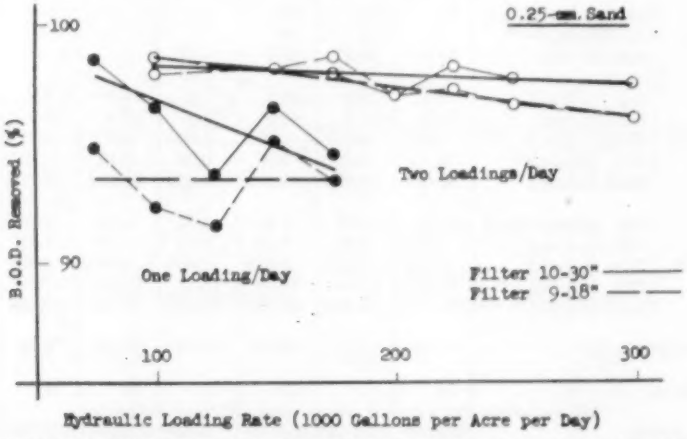

FIGURE 3.—B.O.D. removals by sand filters 9 and 10 under one and two loadings per day.

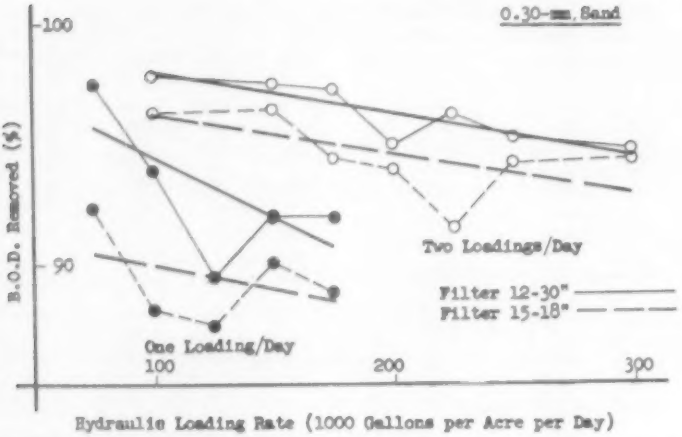

FIGURE 4.—B.O.D. removals by sand filters 12 and 15 under one and two loadings per day.

Discussion of Results

Figures 3, 4, 5 and 6 show graphically the percentage reduction of the applied B.O.D. at both one and two loading increments per day when the loading is measured hydraulically (gallons per acre per day).

Figures 7, 8, 9 and 10 show the per-

TABLE VI.—Test Data for Unit 12; Sand Size, 0.31 mm.; Bed Depth, 30 in.

Loading (1,000 g.p.a.d.)		100	150	175	200	225	250	300
No. of samples		9	17	7	35	14	15	32
B.O.D.	infl. (p.p.m.)	136	160	143	96	106	84	133
	infl. (lb./a./day)	113	200	208	160	198	175	332
	effl. (p.p.m.)	3	4	4	5	4	4	7
	removal (%)	97.8	97.5	97.2	94.8	96.2	95.2	94.7
S, sol.	infl. (p.p.m.)	93	105	87	—	—	—	—
	effl. (p.p.m.)	5	8	6	—	—	—	—
	removal (%)	94.6	92.4	93.1	—	—	—	—
N	infl. org. (p.p.m.)	19.1	18.6	15.2	7.6	6.1	9.2	25.2
	infl. NH_3 (p.p.m.)	16.8	17.1	19.2	20.3	24.4	19.5	24.0
	infl. NO_2 (p.p.m.)	0.007	0.002	0.003	0.003	0.007	0.019	0.038
	infl. NO_3 (p.p.m.)	0.15	0.20	0.59	0.09	0.11	0.20	0.17
	infl. total (p.p.m.)	36.057	35.902	34.993	27.993	30.617	28.919	49.408
	effl. org. (p.p.m.)	1.33	1.07	1.98	1.58	1.04	1.80	4.21
	effl. NH_3 (p.p.m.)	0.93	0.71	2.12	2.15	1.74	1.47	3.88
	effl. NO_2 (p.p.m.)	0.007	0.026	0.002	0.002	0.004	0.008	0.034
	effl. NO_3 (p.p.m.)	32.44	21.69	26.79	16.71	20.95	17.08	16.63
	effl. total (p.p.m.)	34.707	23.496	30.892	20.442	23.734	20.358	24.754
	oxidized (%)	93.48	92.40	86.72	81.75	88.28	83.92	67.27
Air temp., av. (° F.)		74	72	70	71	65	72	68
Test period		3/16/48–7/23/48	7/24/48–2/12/49	2/13/49–7/7/49	7/8/49–1/12/50	1/13/50–3/26/50	3/27/50–7/12/50	7/13/50–3/9/51

TABLE VII.—Test Data for Unit 14; Sand Size, 1.04 mm.; Bed Depth, 30 in.

Loading (1,000 g.p.a.d.)		175	250	300	400	425
No. of samples		9	25	66	33	10
B.O.D.	infl. (p.p.m.)	136	155	96	121	152
	infl. (lb./a./day)	198	323	240	403	538
	effl. (p.p.m.)	25	51	28	30	28
	removal (%)	81.6	67.4	70.8	75.2	81.6
S. sol.	infl. (p.p.m.)	93	100	—	—	—
	effl. (p.p.m.)	15	57	—	—	—
	removal (%)	83.8	43.0	—	—	—
N	infl. org. (p.p.m.)	19.1	17.5	7.6	10.7	12.8
	infl. NH_3 (p.p.m.)	16.8	17.8	20.6	21.8	17.3
	infl. NO_2 (p.p.m.)	0.007	0.002	0.007	0.038	0.021
	infl. NO_3 (p.p.m.)	0.15	0.37	0.12	0.23	0.05
	infl. total (p.p.m.)	36.057	35.672	28.327	32.768	30.171
	effl. org. (p.p.m.)	8.05	10.17	7.72	3.64	4.05
	effl. NH_3 (p.p.m.)	11.62	9.59	12.01	10.37	7.25
	effl. NO_2 (p.p.m.)	0.031	0.079	0.016	0.080	3.64
	effl. NO_3 (p.p.m.)	11.83	9.56	8.56	13.35	17.91
	effl. total (p.p.m.)	31.531	29.399	28.306	27.440	32.85
	oxidized (%)	37.59	32.72	30.63	48.87	62.85
Air temp., av. (° F.)		74	73	70	65	69
Test period		3/15/48–7/23/48	7/24/48–7/7/49	7/8/49–7/12/50	7/13/50–2/9/51	2/16/51–7/13/51

centage reduction of applied B.O.D. at both loading increments when the rate of application is expressed organically (pounds of B.O.D. per acre per day).

Using the method of least squares, a straight line of best fit was put through the averaged data at each loading increment and at both loading

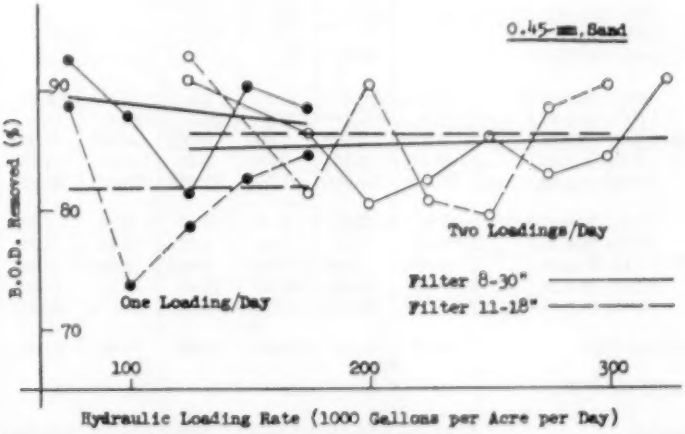

FIGURE 5.—B.O.D. removals by sand filters 8 and 11 under one and two loadings per day.

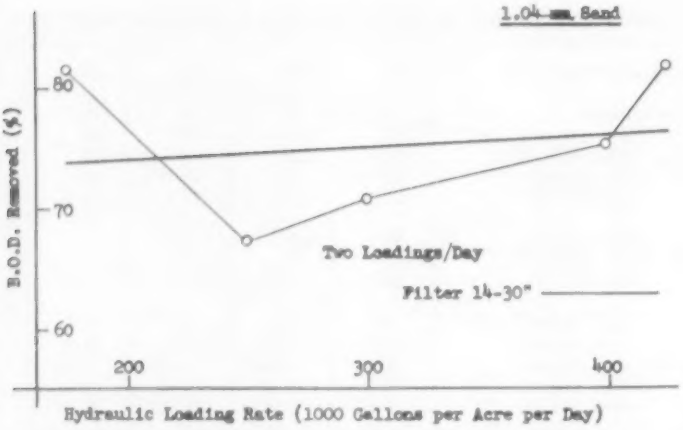

FIGURE 6.—B.O.D. removals by sand filter 14 under two loadings per day.

parameters. Table IX is a summary of the pertinent information.

For the range of the data analyzed it is evident that the relationship which exists between the percentage of B.O.D. removed and the loading parameters studied, whether expressed hydraulically or organically is small.

TABLE VIII.—Test Data for Unit 15; Sand Size, 0.29 mm.; Bed Depth, 18 in.

Loading (1,000 g.p.a.d.)	100	150	175	200	225	250	300
No. of samples	9	17	8	35	14	16	30
B.O.D. infl. (p.p.m.)	136	160	143	96	106	87	124
B.O.D. infl. (lb./a./day)	113	200	208	160	198	181	310
B.O.D. effl. (p.p.m.)	5	5	8	6	9	5	7
B.O.D. removal (%)	96.3	96.9	94.4	93.8	91.5	94.2	94.4
S. sol. infl. (p.p.m.)	93	105	86	—	—	—	—
S. sol. effl. (p.p.m.)	6	11	9	—	—	—	—
S. sol. removal (%)	93.5	89.5	89.5	—	—	—	—
N infl. org. (p.p.m.)	19.6	18.6	15.2	7.6	6.1	8.8	10.3
N infl. NH_3 (p.p.m.)	16.9	17.1	19.0	20.3	24.4	16.6	20.4
N infl. NO_2 (p.p.m.)	0.058	0.002	0.003	0.003	0.007	0.018	0.039
N infl. NO_3 (p.p.m.)	0.13	0.20	0.59	0.09	0.11	0.18	0.27
N infl. total (p.p.m.)	36.688	35.902	34.793	27.993	30.617	25.598	31.009
N effl. org. (p.p.m.)	2.07	2.62	2.73	1.97	2.74	1.86	5.98
N effl. NH_3 (p.p.m.)	1.70	1.94	3.02	2.51	3.46	1.95	4.10
N effl. NO_2 (p.p.m.)	0.009	0.006	0.004	0.003	0.009	0.007	0.057
N effl. NO_3 (p.p.m.)	29.76	23.69	21.75	14.40	18.57	19.59	15.65
N effl. total (p.p.m.)	33.539	28.256	27.504	18.883	24.779	23.107	25.787
N oxidized (%)	88.87	83.85	79.09	76.27	74.96	83.50	60.85
Air temp., av. (° F.)	74	72	72	71	65	70	68
Test period	3/15/48–7/23/48	7/24/48–2/12/49	2/13/49–7/7/49	7/8/49–1/12/50	1/13/50–3/26/50	3/27/50–7/12/50	7/13/50–2/6/51

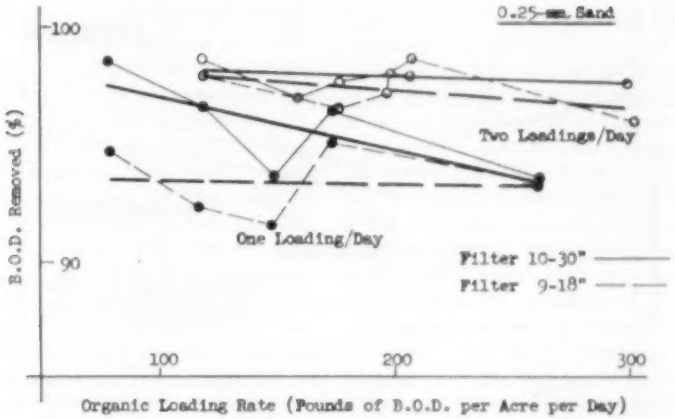

FIGURE 7.—B.O.D. removals by sand filters 9 and 10 under one and two loadings per day.

It is believed that the lack of relationship may be due in part to three causes:

1. The inherent error in the B.O.D. analysis in determining small amounts of B.O.D.;
2. The fact that both carbonaceous and nitrogeneous B.O.D. may be present in the samples (this was discussed by Grantham (5)).
3. The sand filters used in this study were of such depth that they were able to remove 80 to 95 per cent of the applied B.O.D., even though the organic loading rate was sufficient to clog the interstices of the surface sand in a relatively short time.

Thus it appears that the loading parameter for sand beds containing sands with an effective size of less than 0.45 mm. and over 18 in. deep will depend on the amount of organic material trapped in the surface interstices of the filter and on the rates at

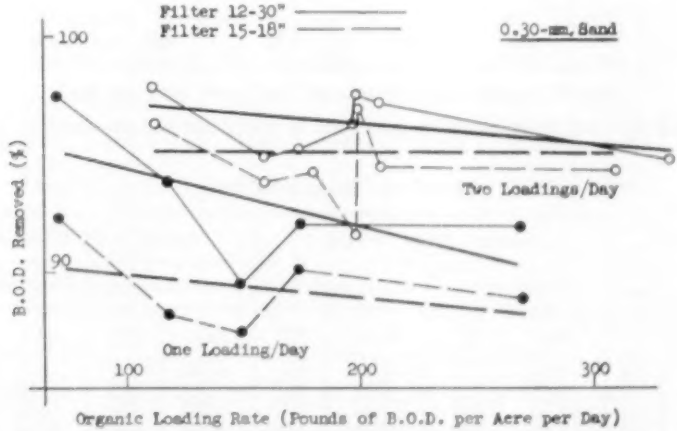

FIGURE 8.—B.O.D. removals by sand filters 12 and 15 under one and two loadings per day.

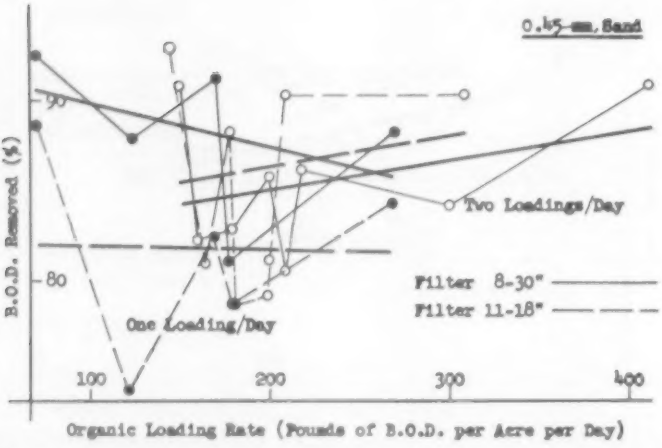

FIGURE 9.—B.O.D. removals by sand filters 8 and 11 under one and two loadings per day.

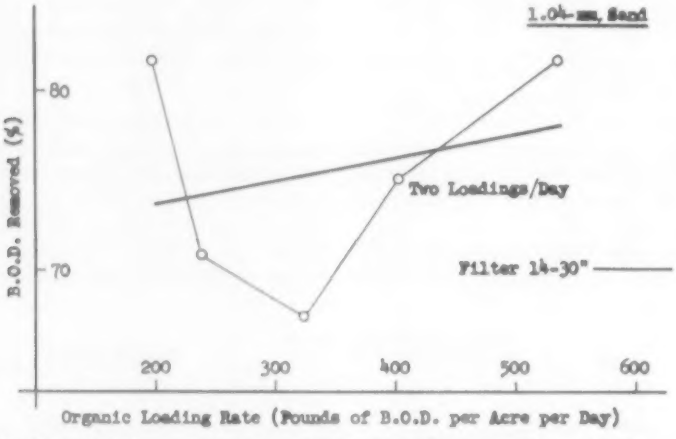

FIGURE 10.—B.O.D. removals by sand filter 14 under one and two loadings per day.

TABLE IX.—Summary of Data

Sand Bed			Loading (1,000 gal./acre/day)				Loading (lb. B.O.D./acre/day)			
			1 Loading per Day		2 Loadings per Day		1 Loading per Day		2 Loadings per Day	
No.	Sand Depth (in.)	Effect. Sand Size (mm.)	Slope	Std. Error	Slope	Std. Error	Slope	Std. Error	Slope	Std. Error
10	30	0.25	−0.040	1.73	−0.005	0.52	−0.023	1.61	−0.003	0.87
9	18	0.25	−0.0003	1.73	−0.012	0.67	−0.001	1.73	−0.008	1.32
12	30	0.31	−0.052	6.02	−0.018	0.69	−0.025	2.61	−0.009	1.28
15	18	0.29	−0.020	2.04	−0.020	1.56	−0.011	2.02	−0.006	1.89
8	30	0.46	−0.021	4.97	+0.003	4.12	−0.021	5.35	+0.017	3.80
11	18	0.44	+0.003	6.45	−0.0004	6.07	−0.002	6.44	+0.016	5.99
14	30	1.04	—	—	+0.009	7.4	—	—	+0.013	7.07

which the biota of the bed can assimilate and oxidize the organic material.

It may be observed from Figures 3, 4 and 5 that the efficiency of the beds in removing the applied B.O.D. improved when the frequency of loading was increased from one to two increments per day. It may also be observed from Figures 3, 4 and 5 that the spread between the lines of best fit of the 18- and 30-in. beds decreased as the frequency of loading increased. This seems to indicate that as the frequency of the dosing was increased the difference between the efficiencies of the 18- and 30-in. beds decreased.

Additional tests were then initiated to determine the effects of loading rates applied in 4 and 24 increments per day. Sand beds 8, 9, 10 and 11 were dosed four times each day (3:00 and 9:00 AM and 3:00 and 9:00 PM). Sand beds 14 and 15 were dosed by means of an automatic dosing siphon so adjusted that the loadings were applied hourly. To secure adequate coverage of beds 14 and 15, spray nozzles were used to distribute the sewage over the surface of these beds. Table X is a summary of the results obtained. From this experiment it became evident that increasing the frequency of loading beyond twice each day increased only slightly the efficiency of those beds containing sands with effective sizes of 0.25 and 0.31 mm. However, it does appear that the efficiencies of beds containing sands of 0.45-mm. effective size and larger are improved when the frequency of loading is increased beyond twice each day.

As previously mentioned, it was believed that one reason why more significant results were not obtained from

TABLE X.—Test Results at 4 and 24 Loadings per Day

Bed number		9	10	15	11	8	14
Sand depth (in.)		18	30	18	18	30	30
Loading (1,000 g.p.a.d.)		300	300	300	300	300	600
Loadings per day		4	4	24	4	4	24
No. of samples		17	15	5	17	28	17
B.O.D.	infl. (p.p.m.)	86	87	42	86	125	104
	infl. (lb./a./day)	215	217	105	215	312	520
	effl. (p.p.m.)	2	2	2	3	6	4
	removal (%)	97.7	97.7	95.2	96.5	95.2	96.1
S. sol.	infl. (p.p.m.)	66	67	—	65	77	59
	effl. (p.p.m.)	6	5	—	8	9	9
	removal (%)	90.9	92.5	—	87.7	88.3	84.7
N infl.	org. (p.p.m.)	16.62	17.16	21.50	16.62	19.67	12.04
	NH_3 (p.p.m.)	13.86	14.19	5.19	13.86	7.39	9.82
	NO_2 (p.p.m.)	0.023	0.002	0.028	0.023	0.023	0.022
	NO_3 (p.p.m.)	—	—	—	—	—	—
	total (p.p.m.)	30.503	31.352	26.718	30.503	27.083	21.882
N effl.	org. (p.p.m.)	1.87	2.09	4.26	2.23	2.48	2.13
	NH_3 (p.p.m.)	0.46	0.47	0.28	0.73	2.73	2.96
	NO_2 (p.p.m.)	0.021	0.019	0.023	0.016	0.038	0.064
	NO_3 (p.p.m.)	9.57	10.14	4.18	8.07	13.00	16.59
	total (p.p.m.)	11.921	12.719	8.743	10.046	18.248	21.744
N oxidized (%)		80.41	79.83	47.89	80.41	71.38	76.53
Air temp., av. (° F.)		79	79	82	79	76	72
Test period		5/9/51–10/5/51	5/9/51–8/6/51	7/14/51–8/6/51	5/1/51–10/4/51	5/1/51–12/10/51	7/14/51–12/31/51

TABLE XI.—B.O.D. Removal by Sand Filter 12 per Unit Depth at Loading Rate of 150,000 G.P.A.D.

Depth of Sampling Point (in.)	B.O.D. Removal (%)	Depth of Sampling Point (in.)	B.O.D. Removal (%)
4	72	18	92
6	83	24	95
12	89	30	97

the investigations of the finer sands (0.25 to 0.31 mm.) was due in part to the fact that the depths used in this study were beyond the critical depth at the loading rates employed. In an effort to determine the critical depth, sand bed No. 12 was rebuilt so that sampling points were available at 4-, 6-, 12-, 18-, 24-, and 30-in. depths. The bed was loaded with primary effluent at a hydraulic loading rate of 150,000 g.p.a.d. applied in two equal doses (at 9:00 AM and 3:00 PM) each day. Influent and effluent samples were collected for a period of 6 weeks and daily analyses made. It was found (Table XI) that 89 per cent of the B.O.D. is removed by passage through the first 12 in. of the bed and the percentage removal of the total applied B.O.D. by the remainder of the bed is very small.

This fact is compatible with results reported by Calaway (7) and by Calaway, Carroll and Long (8) that the common zöogleal organism (*Zöoglea ramigera*) which is believed to be responsible for most of the removal of organic material becomes relatively insignificant below the 12-in. level. Thus it appears that sand filters composed of 0.35-mm. sand or smaller and loaded with primary effluent twice each day under carefully controlled conditions may be reduced in depth to 24 in., and under special conditions to 18 in. When such depths are used, however, care should be exercised to insure that the full depth of sand is maintained at all times, and any sand removed when the bed is raked or scraped should be replaced promptly. When shallow beds are used, the underdrains should be spaced more closely than in deep ones.

Cognizance should be taken of the fact that these conclusions are based on the results of closely controlled laboratory experiments. As such close control is seldom maintained over actual field installations, regulatory agencies may find it desirable to modify these recommendations to some degree so as to comply with existing conditions.

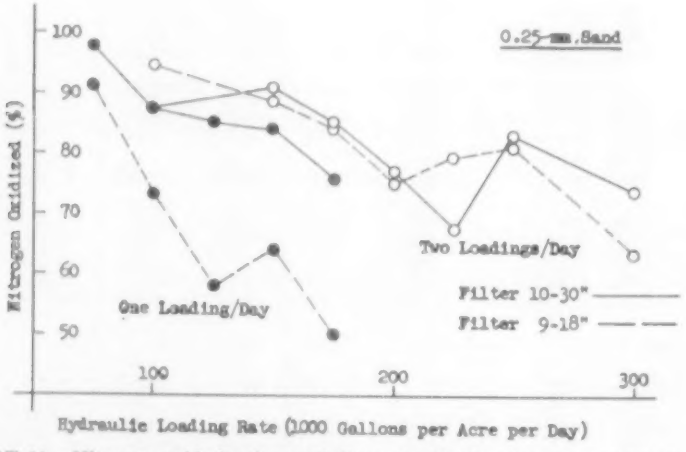

FIGURE 11.—Nitrogen oxidation by sand filters 9 and 10 under one and two loadings per day.

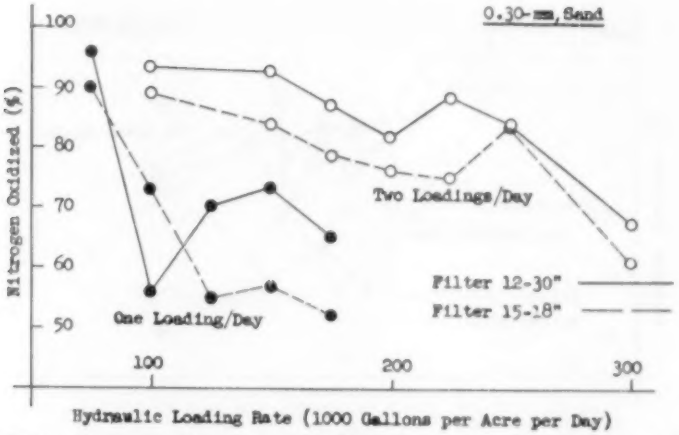

FIGURE 12.—Nitrogen oxidation by sand filters 12 and 15 under one and two loadings per day.

Oxidation of Nitrogen

Nitrogen determinations were included as a part of this study and the results are listed in Tables II to VIII, inclusive. The nitrogen oxidation was determined as the percentage of the total nitrogen recovered represented by the sum of the nitrate nitrogen and 75 per cent of the nitrite nitrogen recovered in the effluent. This was the method used by Grantham (5).

The percentage of nitrogen oxidized is plotted against the hydraulic loading rate for the three pairs of filters in Figures 11, 12 and 13. In Figures 14, 15 and 16 the percentage of nitrogen oxidized is plotted against the organic loading rate. Included also are the results from previous work (5) which allow comparison not only between the filters of different depths, but also between the results obtained at one and two loading increments per day.

From these figures it may be observed that better nitrification is ob-

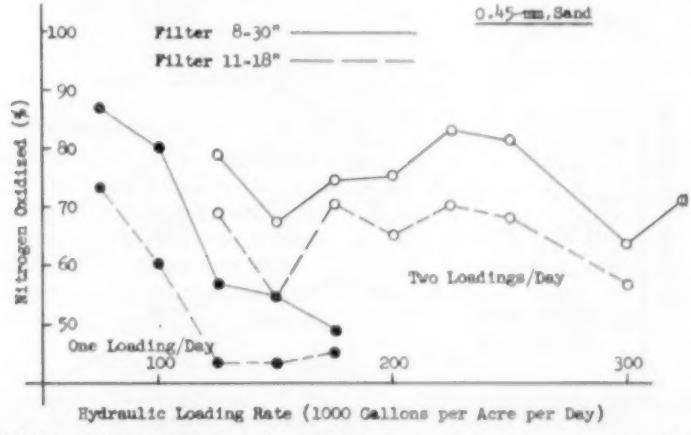

FIGURE 13.—Nitrogen oxidation by sand filters 8 and 11 under one and two loadings per day.

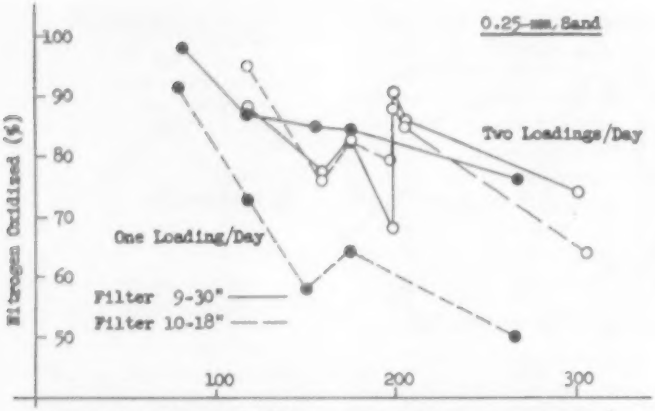

FIGURE 14.—Nitrogen oxidation by sand filters 9 and 10 under one and two loadings per day.

tained when the sewage is applied in two increments per day. It is also evident in the 0.25-mm. and 0.31-mm. beds that the percentage of nitrogen oxidized decreases slowly as the loading rate is increased. This appears to be true at both loading parameters.

In the case of the 0.45-mm. sand it appears that the percentage of nitrogen oxidized is independent of the hydraulic loading rate, but is dependent on the organic loading rate, which is as expected.

It also appears that the difference between the percentage of nitrogen oxidized for both the 30-in. and 18-in. beds is smaller when the sewage is applied in two increments than when the beds are loaded once each day. It was noted in a majority of cases that the total nitrogen recovered at the various levels was less than the total nitrogen applied. Since no specific study was made of this phenomenon it is presumed that there is (a) a nitrogen build-up within the bed, or

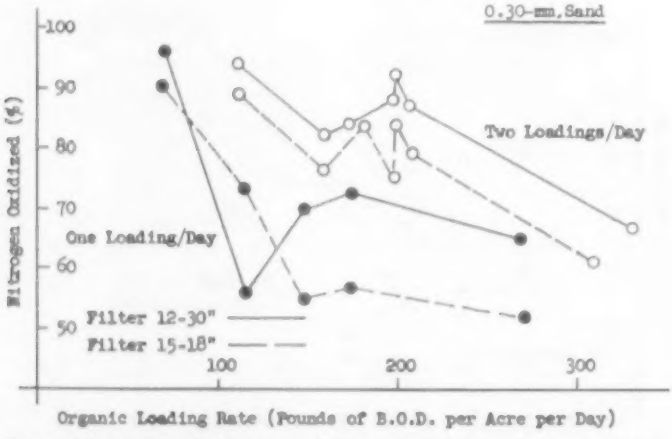

FIGURE 15.—Nitrogen oxidation by sand filters 12 and 15 under one and two loadings per day.

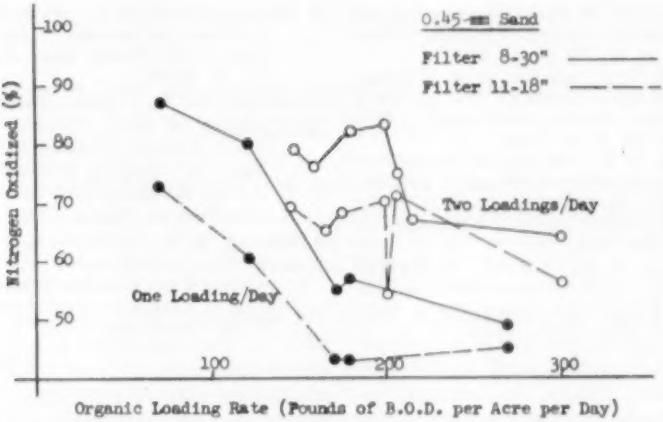

FIGURE 16.—Nitrogen oxidation by sand filters 8 and 11 under one and two loadings per day.

(b) a loss of nitrogen to the atmosphere either during sampling or during the intervals between loadings.

Conclusions

1. Better B.O.D. removal was obtained from both the 18-in. and the 30-in. beds of 0.25-mm. and 0.31-mm. sand when the loading increment was increased from once to twice each day.

2. Increasing the frequency of loading beyond twice each day improves only slightly the efficiency of the beds containing 0.25- and 0.31-mm. sands.

3. The removal of B.O.D. by 0.45-mm. and 1.04-mm. sand beds appears to be independent of the hydraulic and organic loading parameters for the range included in this study (see Figures 5, 6, 9 and 10).

4. The efficiency of the sand beds containing 0.45- and 1.04-mm. sands in removing the B.O.D. is appreciably increased when the frequency of loading is extended beyond twice each day.

5. Increasing the number of loadings per day decreases the difference between the efficiencies of the 18-in. and 30-in. beds.

6. Operating under normal Florida conditions, and loaded with primary settled domestic sewage twice each day, sand filters containing sands of 0.25-mm. to 0.35-mm. effective size will effectively treat 175,000 g.p.a.d.; sand of 0.45-mm. size will treat 200,000 g.p.a.d.; and sand of 1.04-mm. size will treat 400,000 g.p.a.d.

Acknowledgments

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PROPOSED 1956 FEDERAL AIR POLLUTION PROGRAM

There has been increasing evidence that polluted air constitutes a hazard to individual and community health and welfare in certain highly industrialized or large urban areas of the United States. Specific occurrences of smoke, pollution, and fog—now known as "smog"—have been accompanied by excessive mortality and morbidity experiences during periods of their prevalence. Such episodes have happened both in this country and abroad, the latest and most highly publicized occurrences being those which affected Los Angeles in recent years.

The major objective of the U. S. Public Health Service with respect to community air pollution is the provision of suitable control operations by state and local agencies. Aside from the health consequences, economic and nuisance effects have long been of concern and are of increasing importance. Air pollutants contribute to the corrosion of metals, the staining and discoloration of structures and fabrics, damage to crops and livestock, and devaluation of real property. These and similar losses, plus the discharge of incompletely burned fuels and other materials, are estimated to cost the American public more than $1,500,000,000 annually.

An Interdepartmental Committee on Community Air Pollution has been organized to explore the problems, interests, responsibilities, resources and activities of the several Federal departments represented as a basis for formation of Federal policy related to community air pollution.

EFFECT OF PHOSPHORUS ON THE ACTIVATED SLUDGE PROCESS

By Arnold E. Greenberg,* Gerhard Klein, and Warren J. Kaufman

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The need of living organisms for phosphorus is well recognized. The sanitary engineering profession began to take cognizance of this need when Lea and Nichols (4)(5) introduced the now standard B.O.D. dilution water, which contains phosphorus in addition to various other salts. Continuing this line of study, Sawyer (6) determined the phosphorus requirements of activated sludge in the treatment of sulfite waste liquor-sewage mixtures. Still more recently, Helmers *et al.* (1)(2) have reported on the phosphorus requirements of activated sludge in the treatment of domestic sewage as well as a number of industrial wastes.

Although these studies have amply demonstrated that phosphorus is taken up by activated sludge, the manner in which phosphorus in suboptimal concentrations affects the process has not been shown. The use of natural sewages, containing variable and relatively large quantities of phosphorus, made it impossible to study such concentrations. The present study consisted of laboratory experiments designed to evaluate the effect of definite phosphorus concentrations on the activated sludge process. The use of a synthetic sewage made it possible to fix the phosphorus concentration at any desired value.

Laboratory Procedures and Results

The synthetic sewage used, as developed by Weinberger (7), and modified by Kaufman and Klein (3) was further modified by eliminating all phosphorus. Supplemental phosphorus, in the form of $Na_2HPO_4 \cdot 2H_2O$, was added to give the desired phosphorus concentrations—that is, 0.0, 0.1, 0.8, 2.0, and 5.4 p.p.m. The composition and analysis of the synthetic substrate is given in Table I.

The method of developing and maintaining the activated sludge has already been described in detail (3), but for the sake of completeness, a brief summary is given. A batch process was used. The sludges were fed twice daily, at 8:00 AM and again at 4:00 PM. The feeding procedure was as follows: The air supply to the aeration tubes, each containing 1.5 l. of mixed liquor, was shut off and the sludge was allowed to settle for 30 min. One liter of supernatant liquid was siphoned off, 1 l. of substrate containing the desired phosphorus concentration was added, and aeration was resumed. Sludge for the experiment was taken from a system which was developed on the synthetic substrate containing 5.4 p.p.m. orthophosphate phosphorus. The sludge was divided into five equal portions, which, when made up to a volume of 1.5 l., resulted in a mixed liquor containing 1,500 p.p.m. suspended solids. By daily wasting of sludge just before the afternoon feeding, the suspended solids level was maintained as close to 1,500 p.p.m. as possible. From the data on wasting, the rate of growth of sludge was calculated.

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TABLE I.—Composition of Synthetic Substrate

Constituents (mg./l. of tap water)		Average Tap Water Analysis (p.p.m.)		Substrate Analysis	
Urea	60	Sodium	4.0	B.O.D., 5-day, 20° C.	190 p.p.m.
Castile soap	50	Potassium	0.8	Total nitrogen	25.3 p.p.m.
Soluble starch	200	Calcium	4.0	Orthophosphate phosphorus	5.4 p.p.m.
Diatomaceous earth	25	Magnesium	3.3	Alkalinity, as $CaCO_3$	143 p.p.m.
NaCl	30	Alkalinity	20.5	pH	8.0
KCl	7	Sulfate	0.0		
$CaCl_2$	7	pH	8.6		
$MgSO_4$	5	Phosphorus	0.05		
$Al_2(SO_4)_3 \cdot 18H_2O$	25	Hardness	23.6		
$NaHCO_3$	168				

After three weeks of operation, during which the systems appeared to have reached an approximate state of equilibrium, seven series of analyses were made, extending over a 3-month period. Each set of analyses included sludge volatile matter, ash, nitrogen, and phosphorus, as well as the effluent 5-day B.O.D., phosphate phosphorus, and nitrate-, nitrite-, ammonia-, and organic-nitrogen.

As a result of sludge losses due to poor settling characteristics, the suspended solids concentrations of the tubes fed 0.0 and 0.1 p.p.m. phosphorus diminished rapidly. During the period in which sludge and effluent analyses were made, the average solids concentrations of these tubes were respectively, 200 and 510 p.p.m. As shown in Figure 1, these sludges exhibited negligible growth during the course of the experiment. The aeration tubes receiving more than 0.1 p.p.m. phosphorus averaged 1,500 p.p.m. suspended solids. With from 0.8 to 5.4 p.p.m. phosphorus, the rate of sludge growth was proportional to the phosphorus concentration. The leveling off of the curve at the higher phosphorus concentrations indicates that the rate of growth would be affected little by additional increases in the phosphorus content of the substrate.

Differences in the composition of the sludge can be closely correlated with differences in the phosphorus content of the synthetic sewage (Figure 1). The ash content of the sludge increased to a maximum of 24 per cent at a feed phosphorus concentration of about 4 p.p.m. At a level of 0.8 p.p.m.

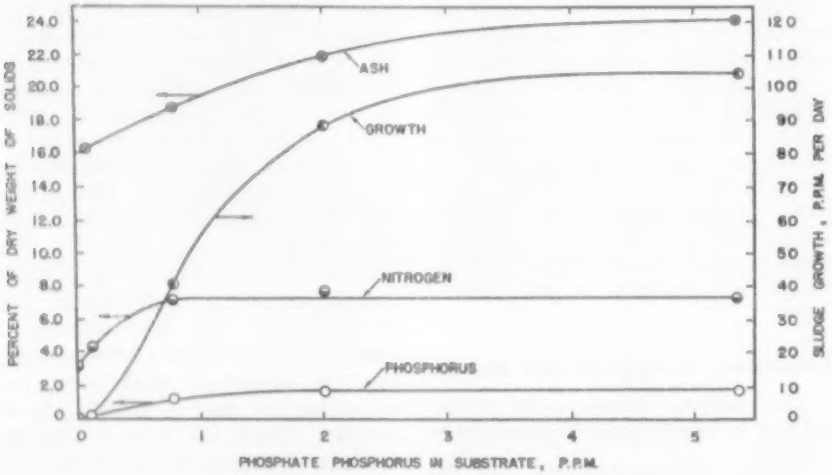

FIGURE 1.—Effect of phosphorus on sludge characteristics.

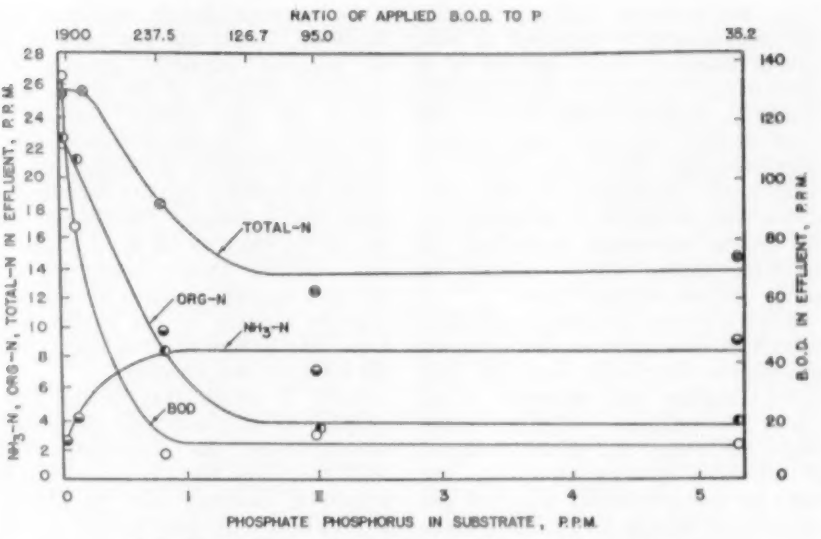

FIGURE 2.—Effect of phosphorus on effluent characteristics.

phosphorus, the nitrogen and phosphorus contents reached maxima of about 7 and 1.8 per cent, respectively. Additional increases in the substrate phosphorus concentration did not affect the nitrogen or phosphorus content of the sludge.

Table II and Figure 2 show the results of the effluent analyses. At phosphorus concentrations of less than 0.8 p.p.m., B.O.D. removal was markedly reduced. Above 1.0 p.p.m., B.O.D. removal remained essentially constant at 95 per cent. Ammonia nitrogen in the effluent increased to a maximum of approximately 8.5 p.p.m. at 1.0 p.p.m. of added phosphorus. Organic nitrogen decreased from 22 p.p.m. to a minimum value of about 4 p.p.m. at 1.5 p.p.m. of added phosphorus. Nitrification was erratic. No nitrites appeared in the effluent when less than 0.8 p.p.m. of phosphorus were added.

Some mention should be made of the physical appearance of the different sludges. Those receiving less than 0.8 p.p.m. phosphorus were whitish in

TABLE II.—Summary of Influent and Effluent Analyses

Item	Phosphorus Conc. in Synthetic Substrate (p.p.m.)				
	Trace	0.1	0.8	2.0	5.4
Average aeration solids (p.p.m.)	200	510	1,480	1,490	1,520
Ratio, substrate B.O.D. to P	—	1,900	238	95	35
Ratio, B.O.D. removed to P removed	—	1,070	230	88	77
Effluent (p.p.m.):					
PO_4–P	0.0	0.0	0.0	0.0	3.1
NO_3–N	0.68	0.64	0.00	0.43	0.53
NO_2–N	0.0	0.0	0.2	2.0	1.2
NH_3–N	2.40	3.90	9.70	7.03	9.22
Org–N	22.26	21.03	8.34	2.79	3.84
Total N	25.34	25.57	18.24	12.25	14.79

color, had a strong tendency to bulk, and microscopically appeared to consist of relatively pure cultures of a filamentous organism subsequently identified as *Sphaerotilus natans*. In these sludges, few microscopic animals were observed. The sludges fed 2 or more p.p.m. of phosphorus were normal in color, settled well, and presented the typical microscopic appearance of activated sludge which included an active microfaunal population.

After a period of three months during which the substrates with different phosphorus levels were used, the feed for all sludges was adjusted to 5.4 p.p.m. phosphorus. Within three weeks, the sludge and effluent analyses of all tubes became essentially the same as that previously reported for the tube containing 5.4 p.p.m. of phosphorus.

Discussion

It has been possible to evaluate the effect of phosphorus on activated sludge from the rates of sludge growth and analyses of sludges and effluents from activated sludge systems acclimated to an identical synthetic sewage containing different amounts of phosphorus.

At a constant B.O.D. loading of 15.8 lb. of B.O.D. per day per 1,000 cu. ft. of aeration capacity, growth and metabolic activity of the sludge were found to be closely related to the influent phosphorus concentration. Sludges previously developed on 5.4 p.p.m. phosphorus rapidly deteriorated when the substrate phosphorus concentration was reduced to 0.1 p.p.m. or less. Growth became negligible and B.O.D. removals, nitrogen uptake, and nitrogen content of the sludge were low. The uptake of phosphorus from the substrate was complete.

Table II shows that in the tubes maintained at these low phosphorus concentrations the suspended solids level were very low. It should not be presumed, however, that the absence of growth and the poor B.O.D. removal were due primarily to the low solids concentrations. In another experiment, the effect of suspended solids concentration on sludge growth was determined with a substrate containing 6.5 p.p.m. phosphorus. The results, in terms of percentage increase in solids as a function of solids concentration, are shown in Figure 3, from which it can be seen that the percentage increase in aeration solids at con-

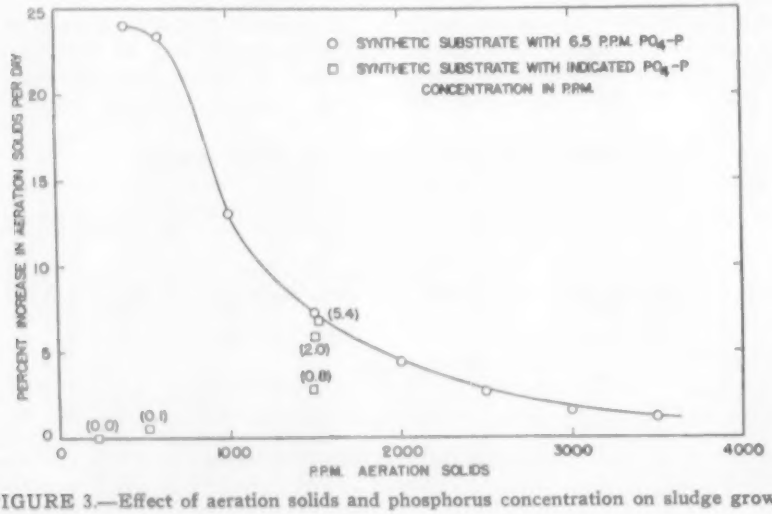

FIGURE 3.—Effect of aeration solids and phosphorus concentration on sludge growth.

centrations of from 200 to 500 p.p.m. would be relatively great in a substrate containing adequate phosphorus. Since the percentage growth in the tubes containing less than 2.0 p.p.m. was below normal, it may be concluded that a factor other than suspended solids concentration was responsible. The absence of growth must thus be attributed to the low concentration of phosphorus in the sewage.

As the phosphorus content in the substrate was increased to between 0.8 and 1.0 p.p.m., sludge growth increased rapidly, B.O.D. removals became 90 per cent or greater, nitrogen removal reached a maximum value of about 53 per cent of input, substrate organic nitrogen was readily converted to inorganic forms of nitrogen in the effluent and to organic nitrogen in the sludge, and phosphorus uptake remained complete while the phosphorus content of the sludge increased to 1.0 per cent. When the phosphorus level in the feed was still further increased, the rate of sludge growth leveled off, and the other parameters, with the exception of sludge phosphorus content, remained unchanged. At 5.4 p.p.m. of substrate phosphorus, the phosphorus content of the sludge was 1.8 per cent.

The "phosphorus requirement" of activated sludge may be considered as the minimum phosphorus concentration necessary to obtain a maximum removal of B.O.D. Under the conditions of this investigation, the phosphorus requirement, in accordance with the foregoing definition, was 0.8 p.p.m., or 0.44 lb. per 100 lb. of B.O.D. removed. This requirement is in no sense a fixed quantity, but is related to the rate of development of sludge solids, which in turn is related to the applied B.O.D. and to the aeration solids concentration. The requirement increases when loading conditions result in high rates of sludge accumulation. Thus, short aeration periods and low suspended solids levels would result in high rates of sludge accumulation and require more phosphorus. Conversely, by increasing the aeration period or aeration solids concentration, the phosphorus requirement may be expected to decrease, since a greater portion of the B.O.D. will be removed by oxidation rather than by synthesis of new cell material. It should be noted that the phosphorus uptake by an activated sludge may exceed its "requirements" if the phosphorus level is more than adequate to maintain a satisfactory B.O.D. removal. An example of this relationship is the sludge which received 5.4 p.p.m. phosphorus and used, but apparently did not require, 2.3 p.p.m. to effect a B.O.D. removal of 95 per cent. Similar examples may be found in the literature (2).

The observations on sludge appearance suggest the possibility that bulking may be associated with a phosphorus deficiency. The major B.O.D. contributing element of the feed is starch. Ratios of starch to phosphorus of 2,000 or greater existed in the phosphorus-deficient tubes. The starch to nitrogen ratio was less than 10. High concentrations of carbohydrates in sewage have often been associated with activated sludge bulking. On the basis of this work, it would appear that bulking may be due not only to a large amount of carbohydrate, but also to a deficiency of phosphorus relative to the carbohydrate.

The rapid recovery of the phosphorus-deficient sludges when adequate phosphorus was available is further evidence of the essential role played by phosphorus in biological treatment processes.

Summary and Conclusions

The effect of phosphorus on the characteristics of activated sludge was studied by observing, over a 4-month period, the behavior of sludges developed on a synthetic sewage to which varying amounts of phosphate phosphorus had been added.

The following conclusions appear justified:

1. Phosphorus deficiencies cause marked changes in the physical and chemical character of activated sludge solids. Most significant is the tendency for phosphorus-deficient systems to produce sludges having poor settling characteristics with a predominance of filamentous organisms.

2. In the complete absence of phosphorus, the development of an activated sludge is not possible. When phosphorus is present in suboptimal concentrations, growth of sludge solids is retarded and B.O.D. removal is reduced.

3. A phosphorus deficiency results in reduced nitrogen utilization. This reflects the reduced rate of sludge growth and the concomitant lesser need for nitrogen.

4. The phosphorus requirement of an activated sludge system may be defined as the minimum concentration of phosphorus permitting maximum B.O.D. removal without causing an impairment of the sludge settling characteristics. This requirement depends primarily on the rate of sludge growth, which, in turn, is dependent on B.O.D. loading and aeration solids concentration.

5. At a B.O.D. loading of 15.8 lb. per day per 1,000 cu. ft. of aeration capacity and a suspended solids concentration of 1,500 p.p.m., the phosphorus requirement was 0.8 p.p.m. This corresponds to a B.O.D. to phosphorus ratio of 238, or to 0.44 lb. of phosphorus per 100 lb. of B.O.D. removed.

Acknowledgments

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TENTH EDITION OF "STANDARD METHODS"

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FLOW MEASUREMENT IN SEWAGE WORKS *

II. Principal Devices Used †

By Walter H. Brown and George E. Symons

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Flow in sewer systems is usually in conduits partly filled, although it may be under pressure in pipes. Likewise, flow in sewage plants may be in open channels, or in partly full conduits, or in pipes under pressure.

Devices which measure flow in open or partly full conduits are based on a determination of the velocity of flow or some function of it for a known cross-sectional area. The function usually determined is the head (height of liquid level) above the device and these devices are called head-area meters, as will be understood from the discussion which follows.

Devices which measure flow under pressure are known as functional meters, of which there are several, as pointed out previously. These devices also measure some function of velocity, as is shown later.

Head-Area Meters

Measurement of flow in open channels may be performed either on a temporary or on a permanent basis. Temporary operations are usually confined to sampling studies on interceptors, sewers, industrial wastes, or conduits in a plant. Permanent installations are usually made on plant influent lines, tributary sewers, and industrial waste outlets.

Weirs

A weir (Figure 2, Part I) consists of a bulkhead or dam containing a recess or notch, through which the sewage flows to fall freely to a level below the crest of the weir; that is, below the bottom of the recess or notch. Weirs are generally used for flow measurement on a temporary basis in sewers, etc.

Weirs may be of four general shapes: rectangular, V-notch, trapezoidal (the Cipolletti weir is trapezoidal with the sides of the notch sloping 4 vertical to 1 horizontal), and Sutro (proportioning weir). Weirs are generally sharp-crested so that the liquid will break cleanly from the crest (Figure 9), although broad-crested weirs may be used.

The height of the surface of the liquid above the weir crest is a function of the velocity of the liquid, and therefore a function of rate of flow, since the cross-section of the weir is pre-determined. The point at which this height (head, h) is measured must be upstream from the weir a distance of at least three times the maximum head to be expected. The reason is apparent from Figure 9, which shows how the liquid "drops" over the weir.

Determination of the head may be made in several ways: (a) a staff gage or rule, the zero mark of which is level with the crest of the weir; (b) a float gage; (c) a plumb bob on measured line lowered from a reference point until the tip just ripples the flowing

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FIGURE 9.—Flow over sharp-crested weir.

surface; or (d) a hook gage, by which a point (metal hook) is raised from beneath until the point just breaks the surface. For float, staff, or hook gages, where the flow is turbulent, a stilling well may be used, as with the Parshall flume (Figure 12).

Substitution of the value of h in the proper formula for a particular weir will give the rate of flow. For example, for the rectangular weir, one formula is

$$Q = 3.33\, L\, h\, \sqrt{h} \qquad (3)$$

in which

Q = Flow, in cu. ft. per sec.;
L = Length of weir, in ft.; and
h = Head, in ft.

There are several other weir formulas also in use.

Rectangular weirs may be constructed in two ways (Figure 10); with ends sharp-edged so that the liquid flow contracts as it passes through (called a contracted weir)or with the ends smooth to allow full flow of the liquid (called a suppressed weir). If a contracted weir is used, the value of L must be multiplied by a factor to obtain the true value of L and hence the correct value of Q. (Use $0.1h$ less than 1.0 for each contraction. Rectangular weirs are seldom used for measuring small flows.

The V-notch weir is best suited for small flows and the angle of the notch is commonly 90° or 60°. Other angles, as low as 15°, may be used for extremely small flows. The formulas for triangular weir flow measurement are:

$$90°—G = 2.284\ (h)^{5/2}$$
$$60°—G = 1.3125\ (h)^{5/2}$$

in which G is flow in g.p.m. and h is in inches.

The trapezoidal weir, particularly the Cipolletti weir, may be used where the channel is large or where the head cannot be great with respect to the width of the weir.

For greater accuracy of measurement, all weir formulas need to be corrected for friction, contraction, and other factors. Fortunately for the average operator, tables and charts (1) (2) are available to give a quick means

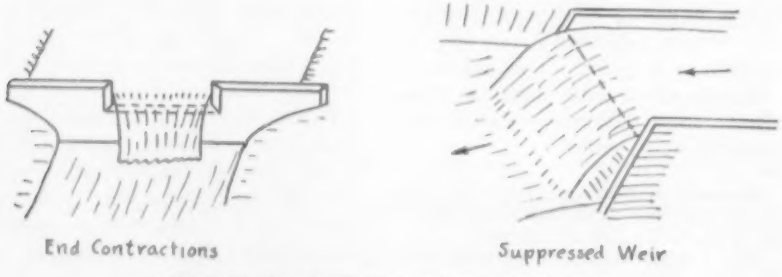

FIGURE 10.—Contracted and suppressed weirs.

of determining Q if the head over the weir is known.

For large sewers and conduits, where the construction of weirs is impossible, flow measurement is made by determining the velocity of flow between two points at different elevations of flow, and calculating a curve relating flow quantities to depth of flow. Such a flow curve is based on the Chezy formula:

$$V = C\sqrt{R\,s} \quad \ldots\ldots\ldots (4)$$

in which

V = Mean velocity, in feet per second;
R = Hydraulic radius, or ratio of cross-sectional area of the stream to the wetted perimeter (See Figure 11);
s = Slope of the hydraulic grade line or slope of the water surface; and
C = A coefficient which varies with V, R, and s according to Kutter's formula, wherein n, a factor of roughness of conduit surface, is introduced. Kutter's n ranges from 0.01 for very smooth surfaces to 0.035 for very rough surfaces.

Another popular variation of the open channel flow formula is the Manning formula:

$$V = \frac{1.486}{n} R^{2/3} s^{1/2} \quad \ldots\ldots\ldots (5)$$

in which n is the same as Kutter's n. Application of these formulas has been greatly simplified by alignment charts or nomograms (3)(4), which are easy to use. Formulas for open channel flow are not exact, but they do give a good approximation if the conduit or channel is well constructed.

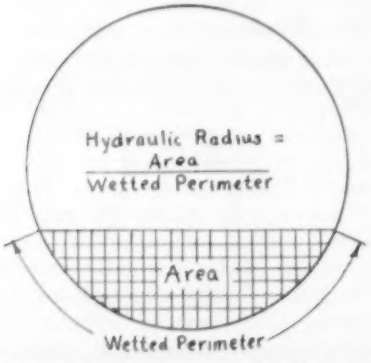

FIGURE 11.—Concept of hydraulic radius.

The fundamentals of weir and flow measurement in open channels are to be found in sewage works literature (1)(5) and in standard texts on hydraulics (6)(7)(8). Weirs are recognized as inexpensive and simple devices, which, however, have definite limits of use. Settleable solids, floating matter, and stringy material tend to deposit from liquids, either in the approach area or on the crest of a weir itself. When this occurs, the flow formula for that particular weir no longer holds and data obtained from it will be in error.

Parshall Flume

The Parshall flume is a widely used head-area type of meter. It is an adaptation of the Venturi flume, which was an adaptation of the Venturi tube principle to open channel flow measurement. Parshall flumes require exacting construction limits, which keep costs high.

The Parshall flume consists of an entrance section with converging walls and level floor, a constricted throat section with parallel walls and downstream sloping floor, and a recovery section with diverging walls and a rising floor (see Figure 12). A stilling well and tap are placed in the converging section at a point two-thirds of the length of the converging section, above the crest of the flume. The tap is at right angles to the wall and at the invert level. Dimensions of Parshall flumes must be held to close tolerances. To improve the accuracy of this measuring device, liners are often used for the approach and throat sections. These liners are of corrosion resistant material.

Parshall flumes are most useful where a minimum head loss through

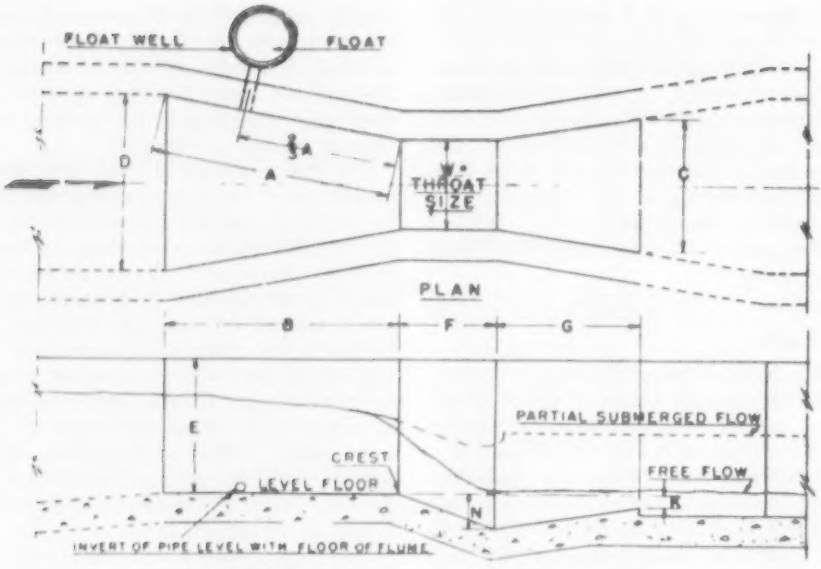

FIGURE 12.—Plan and profile of Parshall flume.

the device is available, but their accuracy depends on the downstream elevation (head above the floor) being held to less than a definite percentage of that upstream. Under conditions of free flow the elevation of the liquid downstream has no effect on the rate of discharge. Under conditions of submerged flow, where the downstream elevation is sufficient to cause a backingup, the rate of flow through the flume will be retarded.

Meters for Parshall flumes are calibrated for free flow conditions and will not correctly measure submerged flow greater than certain limits. The degree of submergence is determined by measuring two heads: H_a at the upstream tap, and H_b at a tap located 2 in. upstream and 3 in. vertically above the intersection of the plane of the throat floor and the plane of the diverging section floor.

For degrees of submergence greater than 70 per cent ($H_b/H_a = 0.7$) in flumes of 1- to 8-ft. throat width, and 60 per cent for throats less than 1 ft. wide, the observed readings will be incorrect and special correction factors must be applied.

For sewage works that contemplate increases in flow over the years, a Parshall flume can be constructed of ultimate dimensions and smaller, removable approach and throat sections installed for low flows. Nested removable sections can be used to provide gradually increasing ranges, but gages must be calibrated for each size throat. Basic data on the Parshall flume have been published (9).

Flow Nozzle

Flow nozzles (Figure 13) are specially constricted outlets for placement

FIGURE 13.—Discharge profile of Kennison nozzle.

at the end of a pipe flowing partially full and must discharge to a free fall. The design of the constriction is such that the head (depth) of the liquid within the nozzle bears a definite relation to the flow.

Two types of nozzles are available. In one (Figure 13) the head has a direct straight-line relation to flow; that is, every unit increase in flow produces the same increment in head. In the other, the relationship between head and flow is a parabolic curve; that is, each unit increase in flow produces a smaller increment in head.

There are other major differences between the two devices, both in construction and field installation, but both require a free fall and the loss of head through the device will be at least one pipe diameter. Flow nozzles require a length of straight pipe immediately preceding the nozzle and the slope of the approach pipe must not exceed certain limits for different size nozzles. If this slope must be exceeded, the length of straight-run pipe ahead of the nozzle must be increased by an appropriate factor.

Flow nozzles are factory-calibrated and have good accuracy over a wide range of flow. Where abnormal installations exist, calibration should be under conditions identical with field conditions. A connection can be made to the nozzle through a sediment trap to attach a direct-reading level gage or through a float well or pressure pipe to other types of mechanical gages.

Flow nozzles (available up to 36-in. diameter) normally are self-scouring and will pass relatively large solids without clogging. Use of flow nozzles for heavy sludge, however, is not recommended unless calibration is for such use. Any deposition will alter the contour of the nozzle and its flow characteristics. For this reason the top of the nozzle is left open for inspection and cleaning in case some peculiar condition of operation causes a deposition.

Differential Head Meters

The most popular and most accurate flow measuring devices are the differential producers. These function by means of some form of constriction in the device, which causes a change in velocity of flow accompanied by a change in pressure (head), which change bears a definite relation to the rate of flow.

Fundamentals of Flow Relations

In order to understand the functioning of differential head meters, it is necessary to elaborate on the general concept of flow and to explain some of the fundamental relationships existing in fluid flow (10).

A liquid has energy (capacity to do work) because of its elevation, velocity, pressure, or any combination of these. Each of these sources of energy may be expressed in terms of equivalent head in feet (or p.s.i.) and each can be converted into the other two.

If a liquid flowed through a smooth pipe without friction, the sum of the three forms of energy, or total head, would remain the same at all points in the pipe, even if the diameter or elevation of the pipe changed.

The word "head" is used frequently in flow measurement and the various kinds of head must be understood. Potential energy, or energy of position, of a liquid is due to its elevation above some point. The height above that point is called *elevation head*.

When a liquid flows in a pipe, a part of the total head is converted into kinetic energy (energy of motion) capable of lifting the liquid through a height called the *velocity head*. If there were no friction, liquid flowing through a pipe between two elevations would have the same velocity as a body falling freely between those same two elevations. The energy of velocity will lift a liquid in a Pitot tube to the height of the original elevation (less friction) or to the difference between

the elevations of the liquid in Tanks I and 2 in Figure 14.

Pressure head is equivalent to the pressure per unit of area exerted on the walls of the pipe. It is equal to the difference in elevation between the hydraulic grade line and the centerline of the pipe (Figure 14).

Total head at any point in a system is equal to the sum of the elevation head, pressure head, and velocity head.

Friction head is the loss of head due to friction, turbulence, pipe roughness, valves, elbows, and fittings, and friction forces when water flows from one point to another. In Figure 14, the friction head is the difference in total head at points 1 and 2. Also shown in this figure is the *hydraulic grade line,* which is a line, in any selected plane, connecting all points representing pressure head in any system.

Theory of Differential Meters

In any pipe, regardless of friction or variations in the cross-sectional area of the pipe, an equal quantity of water must pass all points during the same time interval. This is known as *continuity of quantity* and is fundamental in the functioning of any differential head meter.

If a constriction is substituted for the pipe in Figure 14, as is done in Figure 15, and piezometer tubes are installed at points 1, 2, and 3 and a valve at the outlet to Tank 2, the theory of a differential head meter may be demonstrated. With the valve closed, there is no flow and the liquid will stand in the piezometer tubes at the same elevation as the free surface in Tank 1.

When the valve is opened, the difference in elevation between the two tanks will cause flow from Tank 1 to Tank 2. Part of the total head will be converted to velocity head at point 1. Since an equal quantity must pass both throat and inlet during the same time, the velocity at the throat will have to increase proportionately to the decrease in area. At the same time, as the velocity increases, the velocity head increases and hence pressure head decreases; the greater the velocity, the lower the pressure head at the constriction.

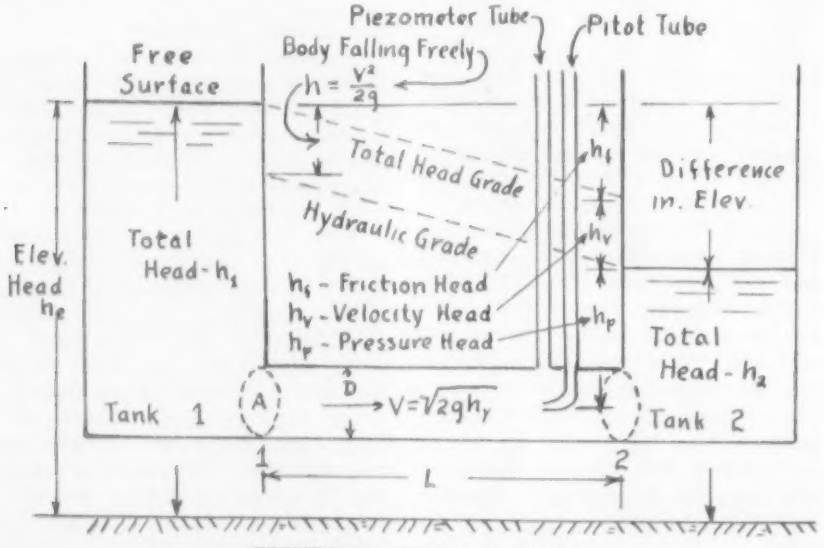

FIGURE 14.—Head relationships.

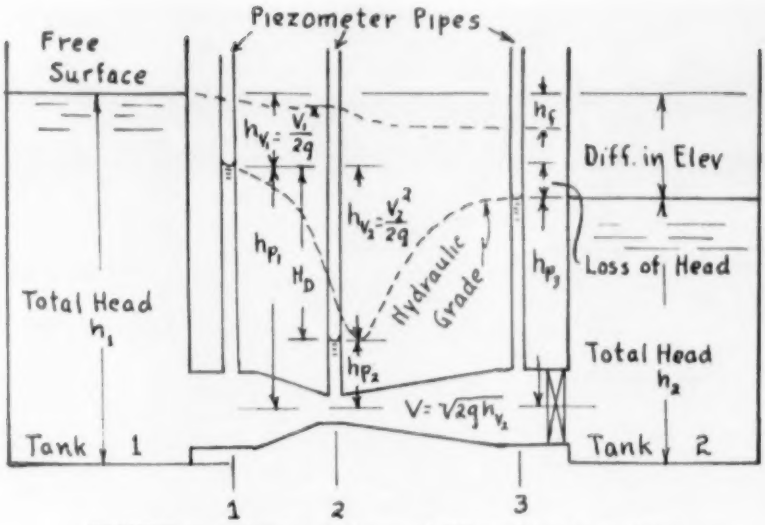

FIGURE 15.—Diagram of theory of differential head producer.

Therefore, the difference in pressure head or differential head (H_D in Figure 15) between the inlet and the throat is a measure of velocity, which is a measure of rate of flow, with the flow varying as the square root of the differential (see "Concept of Flow," Part I). The increase in velocity is equal to $\sqrt{2g\,h_v}$, where h_v equals differential head and the flow formula then becomes

$$Q = A\sqrt{2g\,h_v} \quad \ldots\ldots\ldots (6)$$

Loss of Head

As previously pointed out, a liquid does not move from one point to another without friction; therefore part of the pressure head is lost in movement of the liquid. In any differential head producer, there will be a decrease in pressure head, but a portion of that decrease will be recovered as the flow continues on through the line. Any constriction in a line increases the friction of flow and hence increases the loss in pressure head between the inlet and outlet (points 1 and 3, Figure 15). It is possible to construct devices which can recover a substantial portion of the head decrease at the constriction. That head which cannot be recovered is called permanent loss of head.

Since permanent loss of pressure head requires power to be overcome, a device which creates the lowest head loss is desirable for flow measurement. The smaller the constriction in relation to the original pipe size, the greater the head loss. Also, the smaller the constriction in relation to the pipe, the greater the differential pressure and hence the greater accuracy of measurement. This ratio of inlet diameter to constriction diameter, or d/D, is known as the beta ratio, β, and is expressed as a decimal.

Venturi Tube as Differential Producer

The Venturi tube is essentially a section of pipeline in which it is installed to measure flow. In itself, the Venturi tube usually consists of several sections (see Fig. 16), including a conical reducing section, a cylindrical throat section, and a divergent outlet cone.

The inlet section consists of a short cylinder, A, and a truncated cone, B.

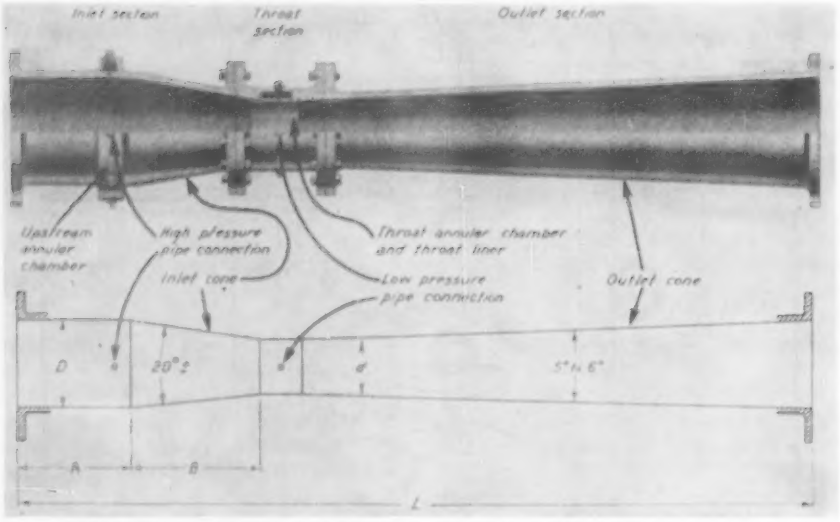

FIGURE 16.—Elements of Herschel standard (long) Venturi meter tube.

The inlet section usually contains a piezometer ring or annular chamber (also called an annulus), which serves as a means of obtaining the average pressure of the fluid at the upstream point.

The throat section follows the inlet section and is the most constricted part. A piezometer ring or annular chamber also surrounds the throat section to serve as a means of obtaining the average pressure at that point.

The outlet section may be of one or more castings; it follows the throat section and is essentially a long truncated cone, which gradually returns to the original size of the pipe line.

The details of design and relations of one section to another, together with the angles involved, lengths, etc., are shown in Figure 16. A variation of the standard Herschel (or long) tube is a short tube which has an outlet cone about one-half as long as that of the long tube. While the length is shorter, the non-recoverable head loss is greater. It is the recovery section with its gradual return to normal pipe size which gives the high recovery of pressure head of 87 to 90 per cent found in the long form Venturi tubes.

Besides the simple determination of the differential head, there are two other factors to be considered in measurement with a differential producer such as the Venturi tube. These factors are the velocity of approach and friction. In a pipeline, flowing liquid has a certain velocity of approach as it reaches the inlet section of the device. At the constriction, then, it has a velocity due to the constriction, plus the original velocity. It is therefore necessary to correct observations of differential head for this velocity of approach factor, and this is done through a table of values related to the beta ratio, d/D (10). This velocity of approach factor is expressed as $1/\sqrt{1-\beta^4}$.

The other factor, friction, causes the apparent value of the flow to be lower than the theoretical value indicated by the observed differential. For this reason, each Venturi tube has a discharge coefficient, C, to correct the observed value to the actual value. Depending on throat velocity and measuring range, the value of C for various sizes of Venturi tubes will be between 0.96 and 0.99. For other

than exact calculations, an average value of 0.98 may be used.

The accuracy of the Venturi tube will normally be in the range of ± 2 per cent, but greater accuracy can be obtained if the tubes are University calibrated. The formula for Venturi tube measurement evolved from considerations of the concept of flow, pressure, velocity, and the necessary correction factors becomes

$$Q = A\,C\,\frac{1}{\sqrt{1-\beta^4}}\sqrt{2g\,H_D} \quad \ldots (7)$$

where Q is in cu. ft. per unit time, A is in sq. ft., C is the coefficient of discharge, β is the diameter ratio (d/D), and h_D is the differential head in feet. By the use of proper additional numerical factors, this formula can be converted into gallons per unit of time.

For special applications, special forms of Venturi tubes are available in addition to the long and short forms. When a Venturi is to be used for metering sludge, the annular ring is eliminated and replaced by single-hole taps at the inlet and throat, and these are flushed continuously with fresh water. Venturi tubes with flat inverts for liquid with high solid content are also available, as is a tube constructed to meter flows in either direction.

Flow Tubes

A new Venturi-type differential producer is also available. Known as the Dall flow tube (Figure 17), it is an accurate primary device having less permanent head loss than any known type of velocity-increasing differential producer. The Dall flow tube consists of a flanged cylindrical body designed with a short straight inlet section terminating with an abrupt decrease in diameter, or "inlet shoulder," which is followed by a conical restriction and a diverging outlet separated by a narrow annular ring or throat, into which

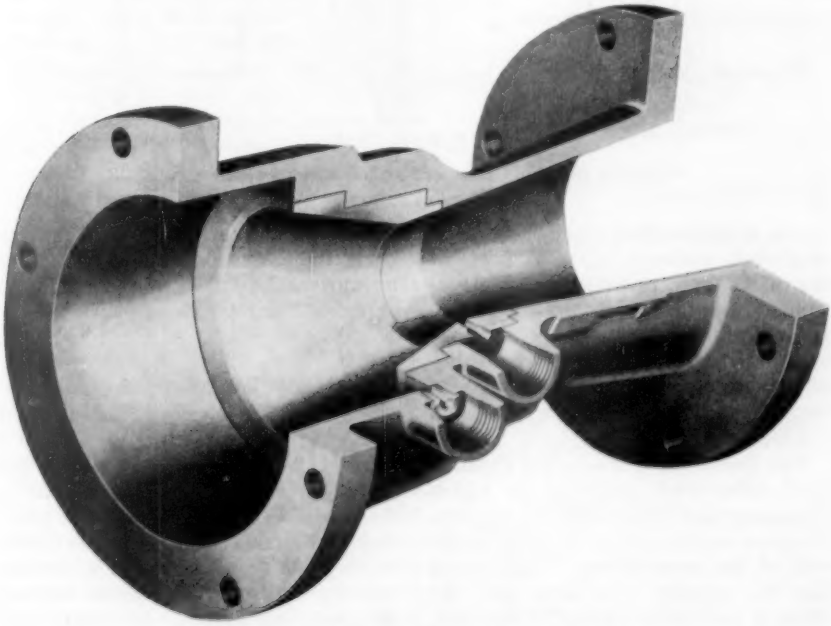

FIGURE 17.—Cutaway section of Dall flow tube.

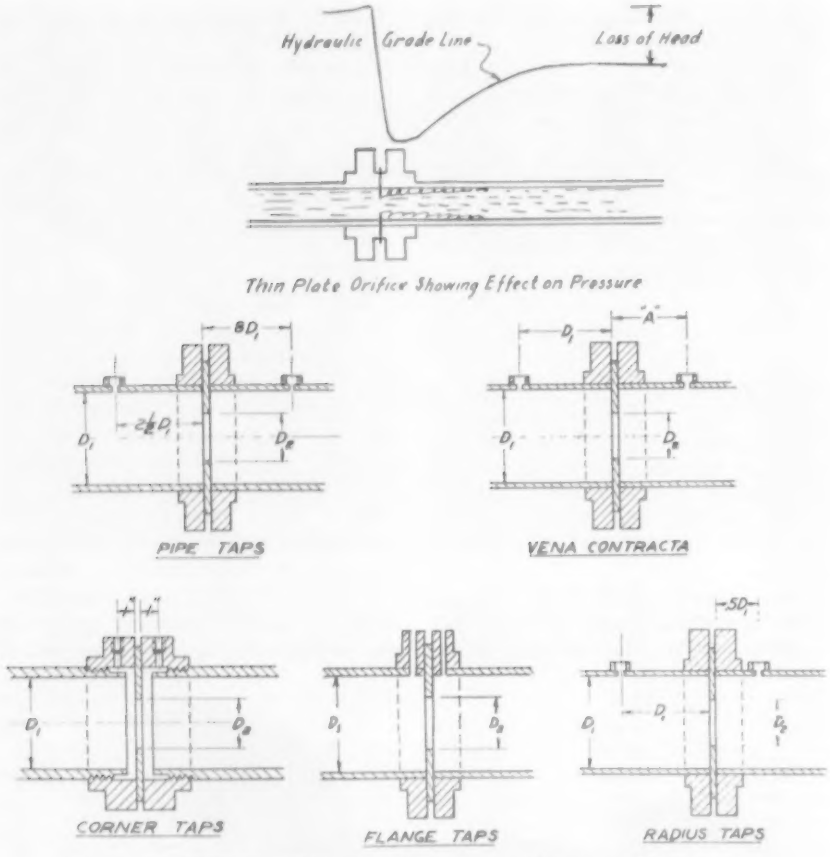

FIGURE 18.—Thin plate orifice and various types of taps.

opens a single pressure-hole tap. A single-hole pressure tap also exists at the inlet. Both pressure taps are continuously flushed with clean water to prevent plugging from solids in sewage or sludge. For measuring flows of liquids containing no solids, the annular ring throat is a narrow gap, called a "slotted throat annulus."

The Gentile tube is another Venturi-type differential producer, in which there is a slight constriction in the line. Pressure nozzles or ports exist in the wall of the constriction. These ports face in opposite directions and the effect is somewhat similar to the multiple-port Pitot tube. Because of the type of construction and size of the ports, the device has limitations for the measurement of flow of liquids which carry solid matter in suspension.

The Orifice

The orifice is probably the oldest device for measuring or regulating fluid flow, having been used in Caesar's time (11). The orifice is a thin flat plate, having a hole in it, inserted in the pipe. The hole in the orifice plate may be a circular opening at the center of the plate (concentric), or a circular opening tangent to the inside wall of the pipe (eccentric). A variation of the orifice is a segmental opening

bounded by the inner wall of the pipe and a chord of that circle (segmental).

The concentric orifice, the most common type, is shown in Figure 18, which also shows the pressure characteristics and the various locations of the taps. There is a slight build-up of pressure just before the orifice, a sudden drop on the downstream side, and a continued drop before recovery starts. The point of minimum pressure (maximum velocity) is known as the vena contracta.

Take-off points or taps for determining the differential pressure may be located at five different places (Figure 18). These are known as flange taps, radius taps, vena contracta taps, pipe taps, and corner taps. Each will produce a slightly different differential head and each will have a slightly different factor introduced into the general formula of differential head producers (Eq. 7).

Flange taps are located in the flanges between which the orifice plate is mounted and require no drilling of the flanges, but taps must be drilled through the pipe wall after assembly of the flange to the pipe. Radius taps are located at fixed points upstream and downstream from the orifice and require careful drilling. Once installed, radius taps need not be relocated when an orifice size is changed. Vena contracta taps also require careful drilling and must be located at fixed points for any given beta ratio. If the orifice plate is changed, they require relocation.

Caution is necessary in the location of orifice plates; they must be placed in a straight run of pipe with no fittings for 10 to 15 pipe diameters upstream and about 5 pipe diameters downstream. If swirls or spirals exist in the flow stream as it approaches the orifice, longer lengths of straight run pipe are required or straightening vanes must be used. (Spiral flow can be caused by elbows in different planes or by pumps and other conditions.)

Orifice plates, like weirs, are in effect dams, behind which solid particles will deposit from liquids containing settleable solids.

The head loss of orifice plates ranges from approximately 40 to 90 per cent of the differential (that is, the recovery is 10 to 60 per cent) depending on the beta ratio (orifice diameter divided by pipe diameter).

Insert Nozzles

Another form of constriction for producing differential head is the insert nozzle, which consists of a concentric throat section smaller than the

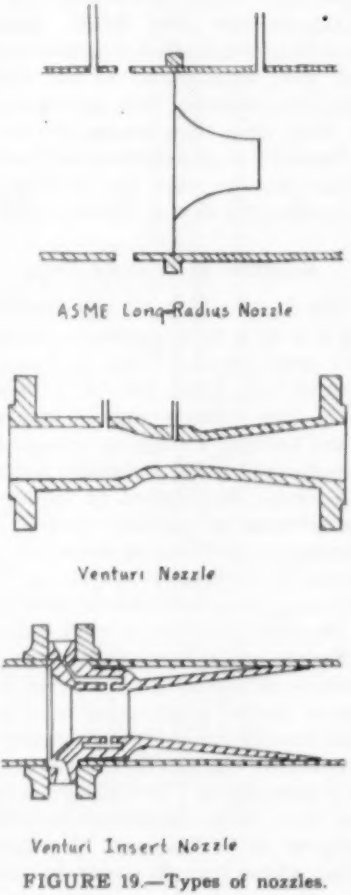

FIGURE 19.—Types of nozzles.

pipe size, inserted in the pipe. (Figure 19). The simplest form, the ASME long-radius nozzle, is in effect an orifice plate with a cylindrical nozzle of the same diameter extending for a short distance beyond the dam. Non-recoverable (permanent) loss of head in this type of differential producer is almost as great as in the orifice and it has the same disadvantages—that solid particles will lodge on the upstream side or may build up on the edge of the opening.

There are several variations of the insert nozzle type of differential head producer, all designed to reduce the permanent loss of head. These include the Venturi flow nozzle, and the Schlag-Jorissen flow tube. Nozzles have been used for sludge measurement, but most applications of the nozzle type of differential head producer are in fields other than sewage treatment. A Saran-lined or stainless steel Venturi nozzle may be used for metering or controlling the flow of corrosive wastes.

Selection of Primary Units

The device which actually measures the flow of a fluid is called a *primary unit* (weir, Parshall flume, open nozzle, Venturi tube, Dall flow tube, orifice, etc.) The primary unit is only one of two parts of a metering device. Before discussing the secondary unit, it is desirable to comment on factors in the selection of primary units. For permanent installations, weirs are infrequently used in sewage works. The following paragraphs are devoted only to the other principal primary units.

Factors which have a bearing on the selection of the primary unit include type of service, engineering considerations, installation conditions, accesories, comparative characteristics, and operator's convenience. Not all of the factors and items mentioned hereafter apply to all of the types of primary units; where they do apply, however, full consideration must be given to the evaluation of each factor.

Engineering Considerations

Engineering considerations include such factors as allowable loss of head; throat size of the constriction; acceptable differential pressure; upstream and downstream flow conditions; type of fluid to be measured; laying length of the unit (that is, length of pipe it will replace in the line); types of ends (flange, bell-and-spigot, concrete coupling); distance to secondary unit; type of unit to transmit the measured data to the secondary unit; corrosion resistance required; cleanouts, inspection holes, and manholes; and construction costs as affected by pits for float tubes, forms for flumes, etc.

Installation Factors

Installation factors must consider the position of the device (vertical or horizontal), piping arrangements, vaults, and possible by-pass installations. Accessories required might consist of straightening vanes, flushing devices (intermittent or continuous), vents, vent cleaners, air chambers, floats, float tubes, sediment traps, seals, etc.

Comparative Characteristics

Comparative characteristics of flow measuring devices must consider accuracy, low cost, high capacity, range, permanent loss of head, life expectancy, suitability for solids-bearing liquids, freedom from field tapping, freedom from upstream disturbances, ability to handle high pressures, and ease of installation. Table II shows a comparison of these various factors on a percentage basis, with 100 per cent representing presence or availability of the desired characteristic and less than 100 per cent representing the degree to which the characteristic is available compared to best obtainable. The values are relative, not absolute. It

TABLE II.—Comparison of Principal Primary Units[1]

Primary Unit	Desirable Characteristic (% of best performance)											
	Accuracy	Freedom from Field Drilling and Tapping	Freedom from Upstream Disturbances	High Capacity[4]	Long Life Expectancy	Low Cost	Low Weight	Range	Recovery of Differential Head	Short Laying Length	Suitability for High Pressure	Suitability for Handling Liquids with Solids
Differential Producers:												
Dall flow tube	99	100	60	68	100	25	72	80	100	95	75	100
Gentile flow tube	97	100	50	100	100	25	60	30	80	100	75	20
Nozzle, ASME	98	25	50	100	100	50	100	60	40	[2]	90	100
Nozzle, Venturi	99	100	70	100	100	25	83	80	86	[2]	90	15
Orifice, concentric	100	0	50	65	80	100	[2]	70	38	[2]	90	10
Orifice, eccentric	98	0	40	65	80	95	[2]	40	38	[2]	90	50
Orifice, segmental	97	0	25	93	80	90	[2]	30	38	[2]	90	50
Venturi tube, long	100	100	100	100	100	15	21	100	94	20	75	90[3]
Venturi tube, short	100	100	100	100	100	20	31	100	86	33	75	90[3]
Open Flow:												
Flow nozzle	98	100	70	85	100	70	70	85	0	90	0	100
Parshall flume	98	95	70	70	95	30	90	70	0	33	0	100
Weir	95	90	70	80	98	70	100	50	0	100	0	20

[1] The device presenting the best performance in the characteristic listed is assigned a value of 100 per cent.
[2] Weight of orifices and laying length of thin plate orifices and nozzle are not comparable characteristics to other devices.
[3] May be increased to 100 per cent by modified design.
[4] "High capacity" is defined as relative line capacity at the same stable differential head.

should be remembered that the characteristic "Recovery of Differential Head" (that is, recovery of pressure drop) for differential producers is a direct measure of power losses and hence of operating costs where pumping is involved. Table II is an adaptation of a similar table originally prepared by Miner (12).

[Part III, to be published in the April 1955 issue, presents and discusses secondary instruments and their selection, as well as controls, operating problems, maintenance, etc.—Ed.]

C. C. RUCHHOFT PASSES

Clarence C. Ruchhoft, noted sanitation scientist and engineer with the USPHS at the Robert A. Taft Sanitary Engineering Center until his retirement due to illness July 1, 1954, died on January 19, 1955.

Mr. Ruchhoft joined the USPHS Laboratory in Cincinnati immediately after graduating in 1921 from the University of Minnesota where he received a B.S. degree in Chemical Engineering. Except for the period, 1924–35, when he headed the Bacteriology Division of the Sanitary District of Chicago, he had been with the USPHS Laboratory in Cincinnati in various capacities from then until his retirement, at which time he was Chief of the Physics and Chemistry Section.

A prolific author, Mr. Ruchhoft had written more than 100 research papers in the fields of stream pollution, sewage disposal and water purification for leading scientific journals both in the United States and in foreign countries.

He also received many honors and awards. In 1950 he received the first annual Eminent Chemist Award of the Cincinnati Section of the American Chemical Society and in 1951 was named Cincinnati's outstanding engineer by the Technical and Scientific Society Council of Cincinnati. In 1954 he received the Emerson Medal of the Federation of Sewage and Industrial Wastes Associations. He also was a member of Sigma Xi national honorary scientific research society.

His executive and committee offices included chairmanship of the American Chemical Society's Division of Water, Sewage and Sanitation Chemistry, and chairmanship of the Society's Cincinnati Section. His committee posts included service on the Research Committee and Standard Methods Committee of the Federation of Sewage and Industrial Wastes Associations, the National Research Council subcommittee on Sewage Disposal in Military Areas, and the Sanitation Study Section of the National Institutes of Health, Research Grants Division.

An authority on the disposal of radioactive wastes, Mr. Ruchhoft served as consultant to the Atomic Energy Commission and the Committee on Radiation Protection of the National Bureau of Standards. He had been a consultant to the U. S. Army, Air Force, and Navy and saw service in the Navy in World War I. He was a member of the Society of American Bacteriologists, American Water Works Association, Central States Sewage and Industrial Wastes Association, and the Engineering Society of Cincinnati.

Mr. Ruchhoft achieved international recognition in his hobby, photography. A leading pictorial photographer, he was an associate of the Photographic Society of America and a member of the Board of Directors for five years. As a Four-Star Exhibitor in international salons, his photographs received many trophies, medals and other awards. One of his specialties was color photography.

Industrial Wastes

BIOLOGICAL PROPERTIES AND BEHAVIORS OF CYANOGENIC WASTES *

By Charles E. Renn

Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md.

This paper presents a summary of experiences with a variety of cyanogenic wastes. The work has attempted to evaluate the interaction of waste-bearing waters and the environment in terms of waste disposal design requirements. In this, the approach is somewhat more critical than that commonly taken by fisheries biologists, conservationists, and others who have been concerned with the "preventive" aspects of waste disposal.

The first phases of the work were designed to discover the tolerable limits of certain waste components to fresh-water fish. This was undertaken in 1950; in the interval the composition of the wastes has been greatly modified, but the findings on the tolerances to cyanide, to lactonitrile, and to acrylonitrile are still pertinent, especially since these were conducted under controlled conditions that precluded loss of volatiles from the water system, and permitted close observation of the test animals. A brief review of the earlier literature will show that loss of cyanide to the atmosphere has yielded widely divergent tolerance data.

It was found, under conditions that precluded loss of volatile toxic components, that young fresh-water fish react adversely to potassium cyanide concentrations exceeding 0.03 to 0.05 p.p.m. N as CN^-. These somewhat lower limits apply under conditions of optimum oxygen concentrations (5 p.p.m. D.O. or higher) and in hard, alkaline waters.

It also was found that lactonitrile, although showing markedly lower acute toxicity than potassium cyanide in alkaline water, yielded tolerance values only slightly less than those for potassium cyanide.

The most significant experience, however, relates to the action of acrylonitrile. Quite contrary to the general opinion existing at the time of the studies, it was found that small fish tolerated much higher concentrations of acrylonitrile nitrogen than they could tolerate as cyanide or lactonitrile. The studies indicate that the tolerable range lies near 10 p.p.m. acrylonitrile nitrogen.

Tolerance Bio-Test Technique

In the 1951 studies, the behavior of seven species of young fish available in the hard-water streams and ponds near the U. S. Fish and Wildlife Service Fish Hatchery Research Station at Leetown, W. Va., was examined. The species used as test animals in the experiments are given in Table I, together with the symbols applied to each in graphic data from experiments described later herein. For identification purposes it is to be noted that "open" symbols are used to indicate experiments with closed, continuous-

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

TABLE I.—Experimental Fish Species and Symbols Used

Fish		Symbol	
Species	Common Name	Running Water	Aquarium
Lepomis machrochirus	Bluegill, bluegill sunfish, bream, blue bream, blue sunfish	○	●
Pomoxis annularis	White crappie	□	■
Lepomis auritus	Yellowbelly, yellowbelly sunfish, redbelly, redbreast sunfish	×	⊗
Notemigonus crysoleucas	Golden shiner, roach, bream		∩
Micropterus salmoides	Largemouth black bass		∪
Pimephales promelas	Blackhead minnow, fathead minnow		❣
Micropterus dolomieu	Smallmouth bass, smallmouth black bass	△	▲

flow dynamic systems, and black or "closed" symbols are used to indicate aquarium-type experiments. A total of 21 aquarium-type experiments and 21 constant-flow, constant-concentration-type experiments were run with these fish.

Aquarium tests using relatively large volumes of water (approximately 20 l. of water per 10 fish of about 3 g. each) were run as preliminary screening tests. Aeration applied to these tanks appreciably reduced their cyanide content with time, so that constant-flow tests in closed systems were applied to concentrations found tolerable in the fixed aquaria.

The mechanical design of the constant-flow, constant-concentration systems is shown in Figure 1. Here the cold water from a 15° C. spring supply is first aerated and then heated to 25° C. to fit the temperature requirements of summer pond acclimated fish. The aerated water flows from a constant-head orifice control, through the closed aquaria submerged in the heating system, at the rate of 15 l. per hour, a rate sufficient to meet the respiratory requirements of 10 small fish in the closed 2-l. system. The test wastes are pumped into the dilution-water stream through a set of metering pumps fed from reservoirs bearing

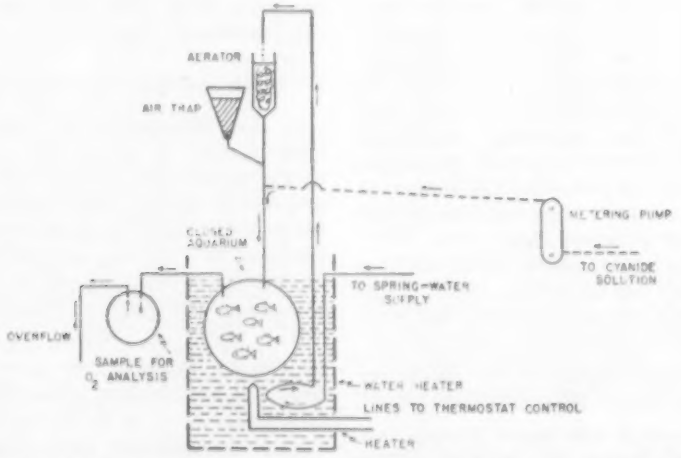

FIGURE 1.—Design of constant-flow, constant-concentration system for laboratory tests.

waste concentrations made up to yield the desired test concentration about the fish. Samples for dissolved oxygen and cyanide content are taken after passing through the test vessel. Note that there is no aeration of the test chamber, and that there is no air-water interface in this part of the system.

Toxicity of Cyanide—Fish Tolerance to Cyanide

Summary results of both aquaria and constant-flow, constant-concentration tests of potassium cyanide are given in Figure 2. It may be seen that in cyanide, 100 per cent survival beyond 10 hr. is uncertain in flowing systems bearing the white crappie when concentrations exceed 0.03 p.p.m. N, and that none of the test species survive for 10 hr. at concentrations exceeding 0.06 p.p.m. N as cyanide. The criteria of tolerance established require 100 per cent survival of the group of 10 fish for 10 hr. or more. It is to be noted here that the plotted data show a sharp break in tolerance to continuous cyanide concentrations at about 0.05 p.p.m. N.

Cyanide and Lactonitrile Tolerances Compared

The survival of young fish in dilute lactonitrile solutions indicates that the tolerance level to this compound lies only slightly higher than that of cya-

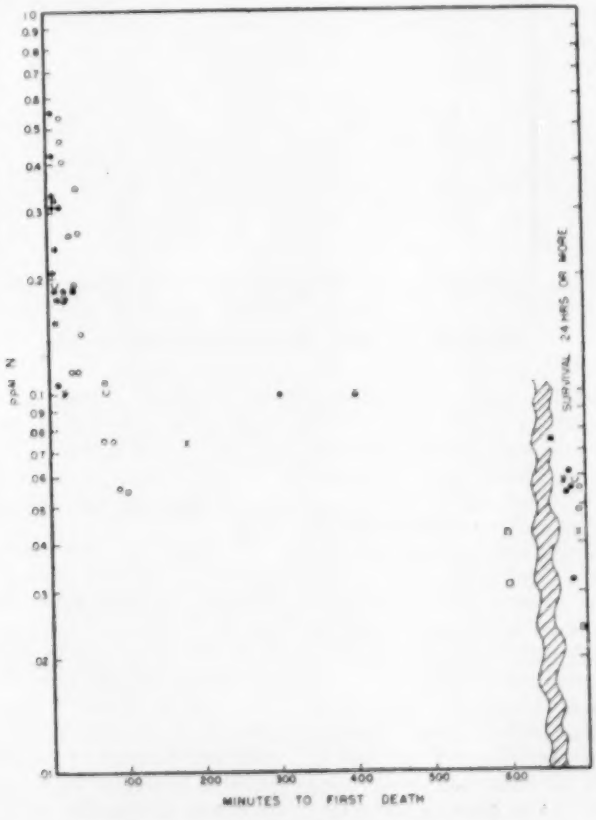

FIGURE 2.—Cyanide tolerance of test species.

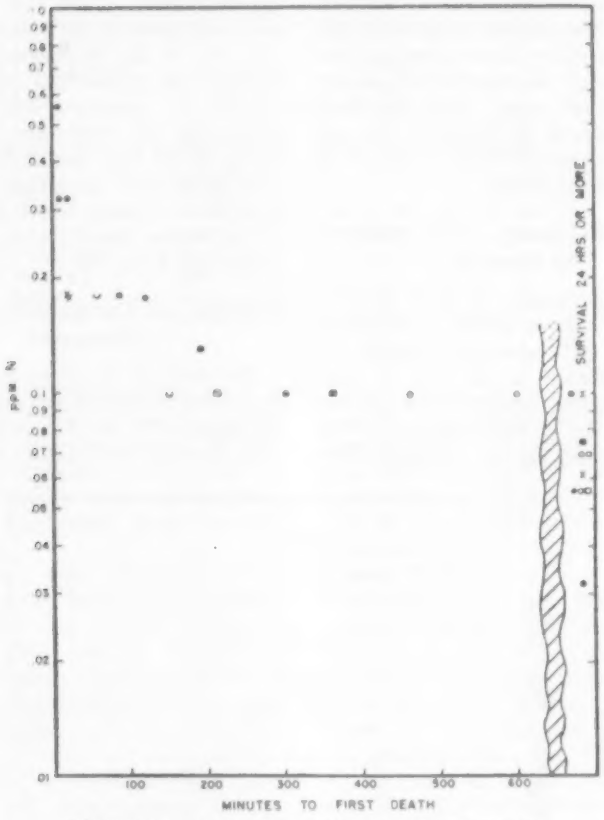

FIGURE 3.—Lactonitrile tolerance of test species.

nide (Figure 3). Again, the data show a sharp break in survival time with rising concentrations, with critical concentrations of slightly more than 0.09 p.p.m. N as lactonitrile.

The existence of steep survival-concentration gradients suggests that fish tolerate cyanide and lactonitrile through successful physiological compensation. This is suggested, too, by comparing the acute toxicities of cyanide and lactonitrile nitrogen by examining Figures 4 and 5, which demonstrate the relationship between concentration and time of survival of 50 per cent of each test group, and show lactonitrile to have an acute toxicity appreciably below that of potassium cyanide. Both groups of data indicate a flattening curve in the range below 0.2 p.p.m. N.

Acrylonitrile Tolerance

At the time these studies were carried out the published literature on the toxicity and animal tolerance of acrylonitrile was in a very unsatisfactory state; biologists in general were somewhat apprehensive, and this view was shared in the original design of these tests for fish tolerance. Daugherty and Garrett (1) established comparable tolerance values for acrylonitrile and lactonitrile. It is interesting that their projection of aquarium-type

test data established essentially the same relationships between lactonitrile and the less dissociated acrylonitrile that the author found.

After some time it was learned that the test fish would tolerate relatively high continuing concentrations of acrylonitrile nitrogen; within the limits of these explorations, this was indicated to be in excess of 10 p.p.m. (Figure 6). Because of the caution observed, sufficient data were not secured at higher concentrations to compare the acute mortality levels of this compound with lactonitrile and cyanide, and it can only be said that the tolerable level lies somewhere above 10 and below 18 p.p.m. acrylonitrile N.

Disappearance of Cyanide in Anaerobic Soil Systems

This leads to a second, less fully explored, but intrinsically more interesting account of later studies. During the course of the toxicity studies various plant run and lagoon effluents were received from the manufacturing process as it then existed. These demonstrated a considerable decline in over-all toxicity with lagoon holding; in all cases the loss of toxicity was directly associated with loss of cyanide as shown in the Leibig analysis.

With long holding and with favorable geography, lagooning appeared to provide a useful degree of waste re-

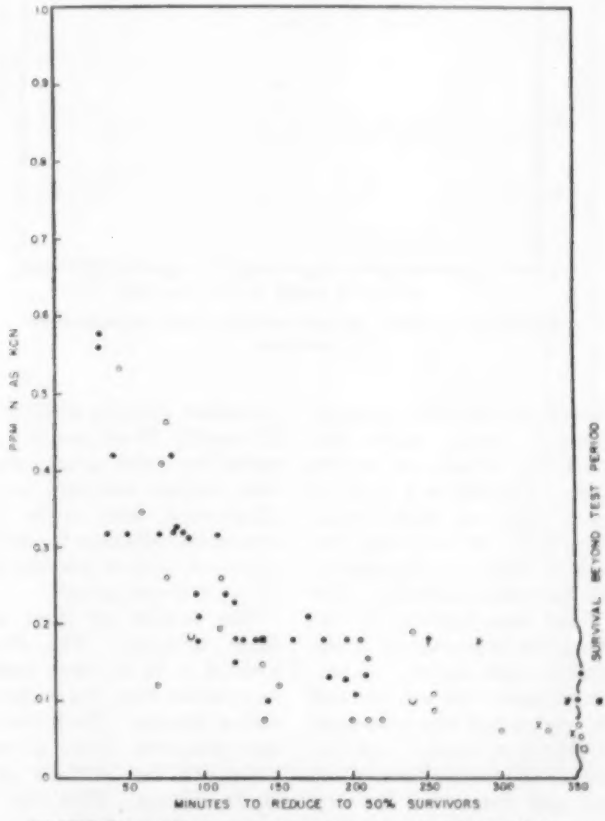

FIGURE 4.—Fifty per cent survival time in KCN solutions.

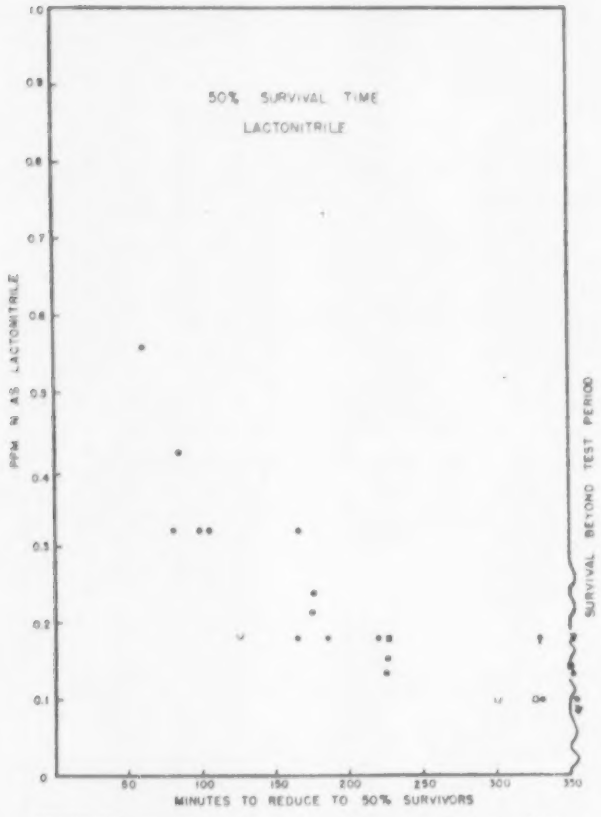

FIGURE 5.—Fifty per cent survival time in lactonitrile solutions.

duction. There was concern, however, that cyanide-rich wastes might find their way, via the subsoil, to potable water supplies. This led to a study of the behavior of relatively high concentrations of cyanide in anaerobic soil systems, such as might be expected to exist in the saturated subsoils below lagoons. There was nothing in the literature to guide expectations at the time the studies were begun. A battery of soil columns was set up and loaded with humus-rich top soils saturated with 100-p.p.m. cyanide and potassium cyanide solution. These tubes were sealed and connected to very small metering pumps that fed added potassium cyanide solution at the rate of roughly 90 ml. per day, a rate estimated to yield approximately 2 per cent volume exchange per day. Arrangements were made to trap the cyanogenic effluents in strong alkali as produced, and to prevent the entrance of air into the system.

The results of these simple tests were striking. The first effluents yielded in 24 hr. were markedly lower in cyanide than the influent, or saturating liquors. There was an immediate reduction from a measured 98 p.p.m. in the influent to 53 p.p.m. in the effluent. With time the cyanide concentration of the effluent declined

rapidly to reach equilibrium value of roughly 0.4 p.p.m. at the end of 20 days. This is shown in Figure 7, which represents the performance of one of the more active columns.

Qualitative changes also were noted. After the second day of exposure, the color of the soil extract was appreciable and it increased in density until at the end of the seventh and eighth days it became necessary to distill the sample for satisfactory colorimetric determination. In addition, gasification occurred within the columns, and the gases collected at the top of the closed systems to force out the effluent at rates higher than the metered displacement. At the end of 30 days, the columns were taken down and soil samples were distilled for residual cyanide content. This distillation was made at room temperature by forcing large volumes of clean air through the acidified soil samples. Maximum cyanide concentrations were obtained at the top of the columns at point of entrance, ranging from 2 to 5 p.p.m. Soil taken from the bottom of the columns showed from 0 to 1 p.p.m. cyanide. The total it was possible to secure was less than 5 per cent of the total concentration of cyanide anticipated from the wet content of the soil columns.

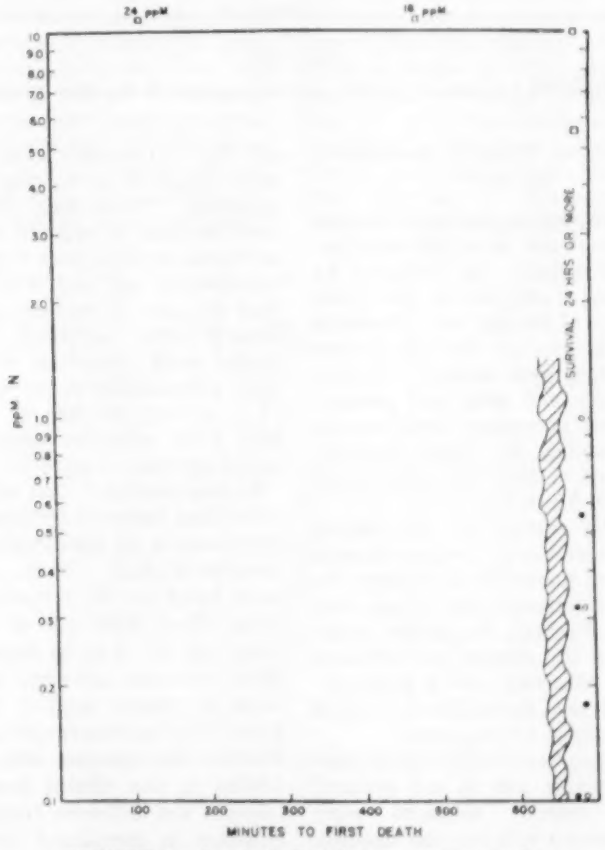

FIGURE 6.—Acrylonitrile tolerance of test species.

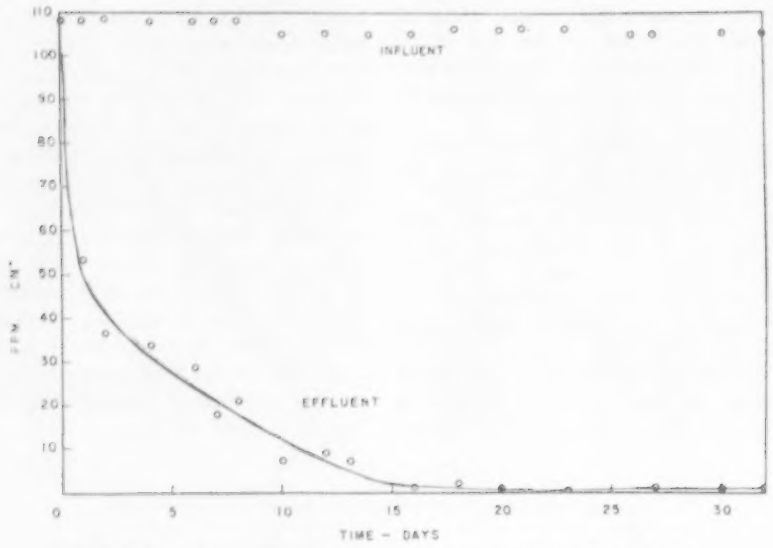

FIGURE 7.—Loss of cyanide with soil passage; 50-day flow through.

Mechanism of Cyanide Breakdown in Soil

No bacteriological studies were made of the soils at this time, although bacteriological activity was indicated by the presence of gas and by the strong buteric odor of the wet soil. It should be noted in passing that the liquors in the system were strongly alkaline, both initially and after soil passage. The influent potassium cyanide solution, containing 98 p.p.m. cyanide, showed a pH of 10.2; the irrigant pH ranged from 9.8 to 10.2.

Superficial biotests of the effluent from the anaerobic soil columns showed a substantial reduction in toxicity. In the lowest dilutions tested (1 per cent of column effluents), the goldfish available for the test showed no evidences of cyanide poisoning over a 48-hr. period. Analytical data indicated that it was in the range of 0.4 p.p.m.

In an attempt to establish the mechanism of cyanide loss in soil contact, potassium cyanide solutions were placed in contact with varying amounts of soil for varying periods of time; and the soil-cyanide solution systems were subjected to varying degrees of agitation. These tests demonstrated that the loss of cyanide from sealed soil-liquor systems rose with increased amounts of soil and with time, and that the rate of cyanide loss also increased with agitation. However, where small quantities of soil were used, substantially at the inocula levels (1 g. of soil per 300 ml. of liquor), very little reduction occurred in the sealed systems (Figure 8).

It was concluded that soil processes other than bacterial fermentation were significant in the breakdown of cyanide systems studied. These conclusions were based on the following observations: First, high pH of the system (near pH 10) may be expected to inhibit bacterial activity; second, the levels of cyanide applied (100 to 200 p.p.m. CN) are commonly bactericidal. Further, the changing rates of cyanide decline in the effluent from the soil columns are different from those anticipated in specialized bacterial fermentations. It is notable that cyanide

assimilation is extremely rapid in the first few days, and that the rate declines with time to yield very low but persisting values in the effluent. Common experience with bacterial fermentations is that initial breakdown is slow, that it rises with the development of the necessary flora, and that it finally stabilizes at a rate fixed by the availability of the substrate.

Effects of Soil Organic Matter on Cyanide Breakdown

A second group of soil studies demonstrated the following additional principles. Cyanide solutions break down on contact with sandy-clay and humus soil in sterilized systems. In sandy-clay type soils, the rate of breakdown in sterile systems is roughly the same as in non-sterile systems. The loss from solutions in contact with humus-rich soils, on the other hand, is marked and more persisting. In the latter case, the continuing loss of cyanide from the soil-waste suspensions suggests some form of biological breakdown. Destruction by fermentation is also suggested by the fact that soils used in early experiments were more active than freshly taken soils.

Relatively rapid removals of cyanide from acrylonitrile plant wastes were secured in short contact periods of one day. Approximately 90 to 95 per cent cyanide removal from 130-p.p.m. cyanide solutions could be maintained over a period of two weeks or more. When the concentrations of cyanide were boosted to 185 p.p.m., the efficiency of removal dropped to 85 to 90 per cent.

Disappearance of Cyanide in Sterile Soil Systems

A demonstration of the experience with soil contact removal of cyanide from potassium cyanide solutions is given in Table II. The preparations were made by sealing 200-ml. quantities of potassium cyanide solution (containing 90 p.p.m. cyanide) in citrate pressure bottles closed with glass stoppers and synthetic rubber washers. The control series contained

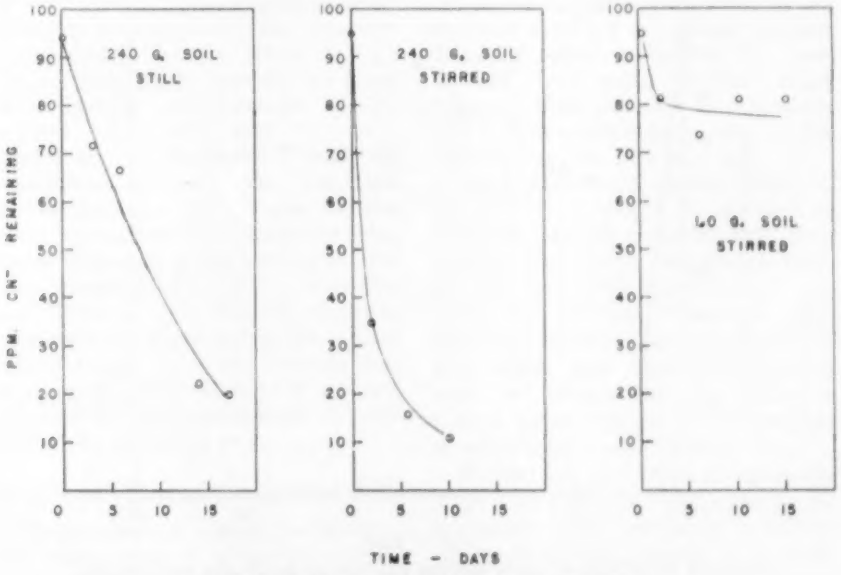

FIGURE 8.—Loss of CN^- with soil contact.

TABLE II.—Breakdown of KCN in Contact with Heat-Sterilized Soil

Test Series	CN^- Concentration (p.p.m.)				
	Initial	Immediately after Sterilization	After Soil Contact	After 7 Days	After 14 Days
A[1]	90	60	—	71	60
B[2]	90	—	70	42	33
C[3]	90	48	—	34	24

[1] Control series; KCN solution, no soil present.
[2] Unsterilized KCN solution plus 100 g. soil per 200 ml. solution.
[3] Steam-sterilized KCN solution plus 100 g. soil per 200 ml. solution.

no soil. Those of series B were also loaded with 100 g. of sandy clay soil, and those in series C were set up in the same manner. Series A preparations, the control bottles, and series C bottles were sterilized in dry steam at 15-p.s.i. pressure for 20 min. Series B preparations were not sterilized, but were allowed to stand at room temperatures (25° C.).

It may be noted that the control series, A, lost roughly 20 to 30 per cent of the initial cyanide on sterilization. In the soil-bearing, sterilized series C preparations, the initial loss with sterilization is somewhat higher. What is important is that the loss of cyanide in these systems containing soil continues with time, until an ultimate loss of 70 to 77 per cent is reached after 14 days.

In the bottles of series B, unsterilized but bearing soil, there is little loss (in the range of 22 per cent) in the short-term contact of preparing the mixture. The cyanide content declines to 37 per cent of the initial concentration after 14 days standing. The point to be considered is that progressive loss of cyanide occurs in both sterilized and unsterilized soil-bearing systems. There is no loss beyond that produced in sterilization in systems that do not carry soil.

Relations of Cyanide Loading Rate upon Soil Breakdown Efficiency

Finally, it is desired to report a soil phenomenon that is not so well de-

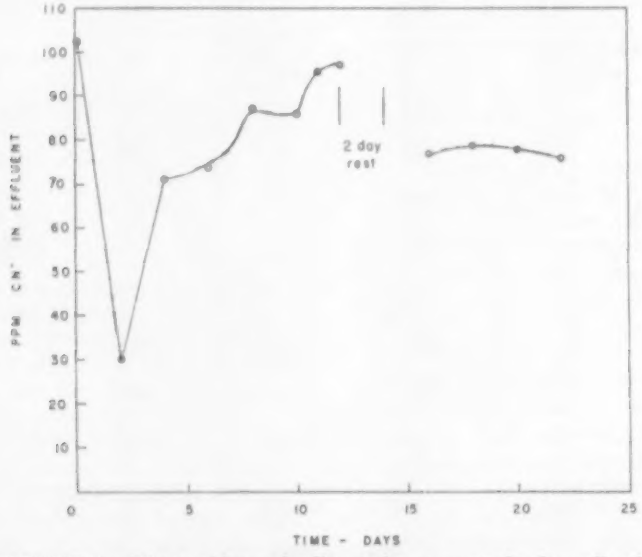

FIGURE 9.—Effects of heavy loading and rest on sandy-clay soil column; 1-day flow-through.

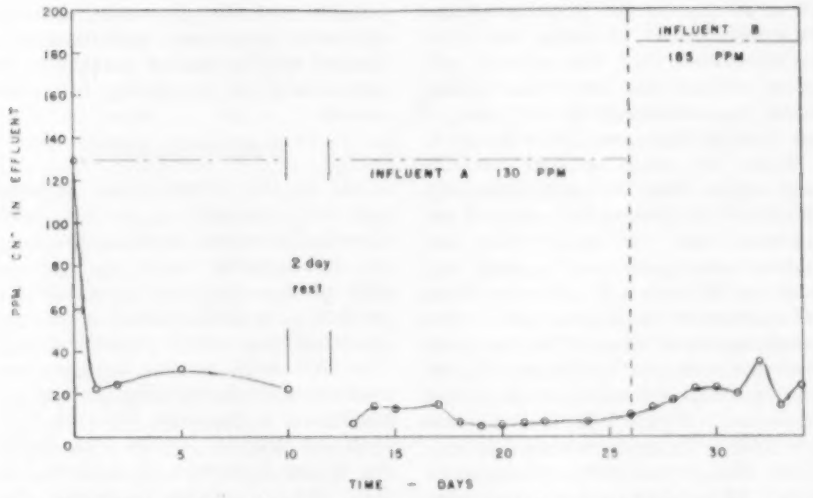

FIGURE 10.—Effects of heavy loading and rest on humus soil column; 1-day flow-through.

fined, but which may have practical significance in designing the disposal of cyanide-bearing wastes into deep soils.

If soil columns are prepared like those described earlier—sealed columns of waste-wetted soil in series with small metering pumps—and these anaerobic soil systems are fed at relatively high rates (using 1-day flow-through times with cyanide concentrations of 100 p.p.m.), the soils may be overloaded so that they become inefficient assimilative systems. This limit has been suggested earlier. Figure 9 shows that an acrylonitrile manufacturing waste diluted to about 100 p.p.m. cyanide content breaks down a sandy-clay soil column in less than two weeks at this loading. After 12 days the column passes almost all of the cyanide that is fed to it. This behavior is in many ways similar to break-through in overloaded zeolyte columns.

Effects of Resting Overloaded Soils

If the column is rested (in this case, two days) there is a rise in cyanide assimilation when feed is resumed at initial rates. Here, roughly 25 per cent of the irrigant cyanide disappeared in transit in the remaining week of the test.

A short check test confirmed the existence of loading limits for efficient performance. Identical columns of sandy-clay soil fed at one-half the rate described before, using two day flow-through feed rates, secured much higher cyanide reductions on passage, and there was little or no drop in the assimilation rate with exposure.

Early experience showed that organic-rich soils might be expected to assimilate cyanide at higher rates than sand or sandy clay. In high-rate feed-through tests with anaerobic soil columns this has been confirmed. Columns of humus-rich topsoil fed at rates even higher than those applied to the sandy soil columns just described show a much higher and more persistent loss of cyanide in transit (Figure 10A).

Within the first day of operation uptake is apparent, and cyanide assimilation levels off to a relatively steady 80 per cent removal from waste solutions bearing 150 p.p.m. cyanide.

After 10 days at this level the column was rested for 10 days, and held sealed. When feed was resumed, efficiency of the system was raised to high levels, approximately 96 per cent of the cyanide disappearing in transit.

There was some concern over the very slight drop in assimilative efficiency on the 10th to 14th days of the resumed run. A check run with higher concentrations of cyanide was made on the same soil column—a form of accelerated breakdown test. The concentration of cyanide in the waste feed was raised to 185 p.p.m. In the results of higher loading on the humus soil column (Figure 10B) it is apparent that raising the concentration does suppress efficiency slightly, to approximately 90 per cent removal in passage. It is also apparent, however, that the column has not been broken down or paralyzed. The assimilation of cyanide in soil transit continues at essentially the same level through the 8-day period of the test.

These explorations into the soil assimilation of cyanide-bearing wastes were found to be very provocative. With the solution of potential pollution problems by reduction of cyanide nitrogen in effluents through improvement of manufacturing processes and controls, the work on this phase of waste disposal research was discontinued. It is possible that this experience, although limited to qualitative and descriptive phases, may be useful to others, the opportunity of presenting it is welcomed.

Acknowledgments

All of the investigations reported here were carried out by the Johns Hopkins University Sanitary Engineering Laboratories under the sponsorship of the American Cyanamid Co. as parts of applied research or as more fundamental graduate research studies. The 1951 work on fish behavior was made possible through the interest and kindness of S. Snieszko, Director, U. S. Fish and Wildlife Service Fish Hatchery Research Station at Leetown, W. Va. The soil column studies on cyanide assimilation or transmission in soils were made by Ray Hawes, then a graduate student, as part of a fellowship program. Thomas Smythe, Jr. and Reid Parramore, also graduate students at the Johns Hopkins University, executed the experimental work on fish toxicity and tolerance, and on soil breakdown of cyanide.

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DISCUSSION

By Clarence M. Tarzwell

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The investigations of Dr. Renn and his staff have produced findings which are provocative and may have significance for the disposal of cyanogenic wastes. The soil percolation tests, in particular, are interesting and deserve more thorough study. Dr. Renn has presented evidence to indicate that biological activity was and was not responsible for the removal of cyanide in the soil systems. It has been established that formaldehyde can be biologically decomposed at a concentration of 1,000 to 1,500 p.p.m. (1)(2). It has also been demonstrated that cyanide does not affect the biota responsible for stream purification as much as it does the higher organisms (3). The initial reduction in cyanide, as indicated by the curves presented by

Dr. Renn, is too rapid for strictly biological activity, but is not the type which would be expected for soil adsorption. Initial adsorption and complexation in the soil might reduce the cyanide content to a level at which the biological utilization of the cyanide could be established. It would be desirable to make bacteriological and microscopic studies of the effluent from the soil columns. It would also be well to analyze the gas released from the soil to determine if it were C_2N_2, HCN, N_2, CO_2, H_2S, or other gases or mixtures.

When cyanide is introduced into a system it has to appear somewhere as a cyanide or as a modified chemical entity. Selective elution should provide information on adsorption, complexation, or ion exchange. Gas analyses and biological examination should give indications of catalytic decomposition or biological activity. The high rate of removal (90 to 95 per cent) over long periods of application would seem to indicate a great adsorptive and/or complexing power of the soils used or a breakdown of the cyanide. The latter is suggested by a build-up of the effectiveness of the soil samples with continued application.

The use of a constant-flow apparatus for the testing of continually renewed dilutions of the toxic materials under consideration is a commendable feature of the author's investigations. It is felt, however, that the results would have been more valuable had the tests been continued for longer periods and the median tolerance limits determined for exposure periods of at least 48 hr. It is doubtful if the criteria of tolerance, 100 per cent survival of 10 fish for 10 hr., would give an adequate measure of acute toxicity. Some materials have little or no effect in 10 hr., but severe effects manifest themselves in 24 to 48 hr. In their report on the standardization of bioassay methods, which appeared subsequent to these studies by Dr. Renn, the Committee on Research, Subcommittee on Toxicity, Section III, Federation of Sewage and Industrial Wastes Associations, has recommended 48-hr. or longer studies for the determination of acute toxicity (4).

In studies at the Sanitary Engineering Center it has been found that hardness or total alkalinity and the pH of the dilution water can greatly influence toxicity. It is understood that in these tests a very hard limestone spring water was used. Under these conditions the toxicity of the test solutions would be less than similar dilutions in a soft water.

It also has been found that pH exerts a tremendous effect on the toxicity of cyanides. In his studies with nickel-cyanide complexes Doudoroff has found that a drop from pH 8.0 to pH 6.5 increases their toxicity more than 1,000 times.

Another factor to be considered is hydrolytic decomposition. If this occurs, the time factor (that is, the age of the solution) deserves attention. Although the dilutions may be freshly prepared and continually renewed, the age of the stock solution pumped may be another matter. Lactonitrile has been found to be quite unstable in a basic medium; it decomposes, with the liberation of free cyanide. This is probably the reason why the lactonitrile solutions tested were found to be much more toxic than acrylonitrile and approached the toxicity of cyanide.

The data presented on the toxicity of lactonitrile and acrylonitrile to fish agree fairly well with those of other investigators (5). Experiments of relatively prolonged duration on the toxicity of KCN to rainbow trout, involving continual renewal of test solutions, have been recently reported by Herbert (6) and Herbert and Merkens (7). The lowest concentration of cyanide tested was 0.07 p.p.m. CN. At this concentration, a temperature of

17.5° C., and pH 7.4 to 8.0, the mean overturning time of yearling rainbow trout was reported to be 74 hr. In 1934, Karsten (8) reported that all of eight 6-in. brook trout died in 130 to 136 hr. at cyanide concentrations of 0.05 p.p.m. in continually renewed experimental solutions.

In work carried out at the Center it has been found that different techniques can lead to widely varying results. It has been determined titration is ineffective on low concentrations of cyanide or in the presence of most complexing agents; that color tests can lead to high or low results, depending upon the form of cyanide present; and that distillation methods may vary appreciably in yield in the presence of different forms of cyanide. In the reporting of results it is desirable, therefore, to define the procedure.

Cyanides can occur in industrial wastes in the form of complex cyanides, some of which have been shown to be much less toxic than free cyanide in solutions with equivalent cyanide content. Further, the toxic forms of cyanide in solutions of complex cyanides cannot always be distinguished readily from the non-toxic forms and measured accurately by chemical means. At the Center the need for bioassay studies in gaining a better understanding of industrial waste problems has been apparent for some time. It is gratifying, therefore, to see the application of toxicology to an actual industrial waste problem as has been done in this instance.

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TENTH EDITION OF "STANDARD METHODS"

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DEPHENOLIZING OF WASTES AND OTHER LIQUORS BY CENTRIFUGAL COUNTERCURRENT SOLVENT EXTRACTION *

By Herbert R. Kaiser

Vice President, Podbielniak, Inc., Chicago, Ill.

In commercial practice the removal of phenolic compounds from ammoniacal liquors produced by coke oven operations has been handled for more than 20 years largely by liquid-liquid extraction. The solvent most generally used is light oil (substantially benzene), which is readily available, relatively inexpensive, and quite immiscible with the aqueous phase.

The liquid-liquid contacting device employed in most plants described in the literature is a packed or spray-type gravitational column. Typical of these plants is one described (1) using light oil, which is subsequently treated with caustic to remove phenol as sodium phenolate, the dephenolized light oil, with or without redistilled make-up light oil, being returned to the extraction step.

Other solvents more selective to phenolic bodies—for example, isopropyl ether, tricresyl phosphate, butyl acetate (2) (3) (4)—are also applicable to the extraction of phenols. The choice of solvent depends largely upon initial cost, selectivity of phenols, immiscibility and recoverability. High miscibility of solvent in the aqueous phase requires stripping operations of large volumes of liquid to recover the solvent.

The gravity separation column is limited in its mixing and phase separation ability. Comparatively speaking, a column is a rather inefficient device for liquid-liquid contacting; it does a better job on vapor-liquid contacting, as in fractionation.

Columns are usually oversized in both diameter and height to take care of any maldistribution of the liquid phases and to obtain the necessary stages of extraction and capacity, which is limited by the rate of phase separation under the force of gravity. Thus, columns require considerable time and volume factors to effect liquid-liquid extraction.

In 1952, the centrifugal countercurrent contactor was applied to dephenolizing waste ammoniacal liquors obtained from several steel plants. The original work was done on a laboratory extractor, followed by tests on 36-in. diameter prototype machines of commercial size, which were subsequently installed in pilot plants of several of the steel companies. This paper describes the Podbielniak centrifugal countercurrent multistage solvent extractor and its performance in dephenolizing ammoniacal liquors.

General Principle of Operation

Figure 1 illustrates the flow of fluids through the centrifugal extractor. Contacting and separating of two liquid phases is effected continuously and countercurrently in the contact elements of the spinning rotor. The lighter of the two liquid phases (light oil) is pumped to the outside of the rotor, while the heavier liquid (ammoniacal liquor) is pumped to the center as shown. The heavier phase flows to the outside of the rotor, dis-

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

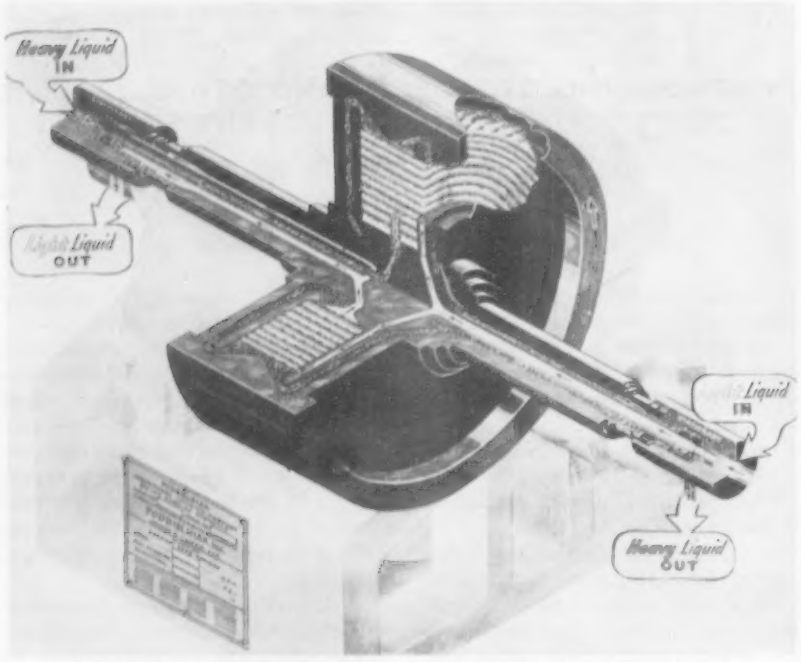

FIGURE 1.—Diagram illustrating flow of liquids through centrifugal countercurrent extractor.

placing the lighter phase and causing it to flow towards the center. The action of the contacting elements within the rotor is to intimately mix and separate in multistage fashion. Quiet zones, near the center and at the large diameter, provide clarification of both streams as they leave the rotor.

Hydraulically balanced pressure-tight seals at each end of the shaft separate the light liquid entering from the heavy liquid leaving, and the heavy liquid entering from the light liquid leaving, and also prevent leakage of effluent streams from the machine. Centrifugal force ranging from 2,000 to 5,000 times gravity (depending upon rotor diameter and r.p.m.) insures positive intimate mixing of the two countercurrently contacted phases to produce in a single compact rotor as many as 10 theoretical stages of extraction.

By suitably adjusting the back pressure of the "light liquid out," the relative volumes of the rotor holdup or the main interface can be controlled and maintained constant, independently of flow ratios. The great force produces centrifugally clarified raffinate and extract at high ratios of throughput to volume holdup.

The contacting elements consist of a combination of perforated concentric and spirally-wound elements analogous to sieve plates used in gravitational columns.

Equilibrium Data for Ammoniacal Liquor-Phenols-Light Oil System

The literature gives the distribution coefficient for phenol into light oil as 2 to 2.5. However, since not only phenol but its higher homologues are to be extracted from the ammoniacal liquor, it was felt that the distribution

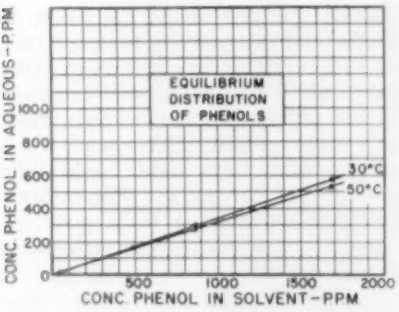

FIGURE 2.—Equilibrium distribution of phenols in aqueous and solvent phases at 30° and 50° C.

coefficient for the so-called "phenols" should be determined before proceeding with either laboratory or pilot-plant testing.

Accordingly, the distribution curve (Figure 2) was prepared at two different temperatures (30° and 50° C.), starting with ammoniacal liquor from plant operations and diluting aliquots with distilled water to obtain a range of concentrations from approximately 16.8 to 1,680 p.p.m. Equilibrium shake-out tests were then performed in the laboratory with equal volumes of dephenolized light oil and ammoniacal liquor. The light oil used had been previously treated with caustic to reduce the phenol content to 1 to 2 p.p.m.

The D. A. A. P. (4-aminoantipyrene) analytical method (14) was used for analysis in preparation of the distribution data and the feed, extract and raffinate streams from laboratory and pilot-plant runs. The data indicate that the distribution coefficient for phenols from ammoniacal liquor into light oil is approximately 3.0 and does not change appreciably with temperatures normally encountered.

Description of Laboratory Extractor

The laboratory extractor used for the dephenolizing tests is shown in Figure 3. The installation consists of two 9-gal. feed tanks (A), one for ammoniacal liquor, the other for light oil. Each tank was pressured with air to force the liquids through the extractor. The flow of each liquid was controlled by a Flotometer (B), while the relative volume holdup was maintained automatically by the back-pressure regulator (C) located at the light liquid outlet. A variable-speed drive (D) with a range of 2,400 to 5,100 r.p.m. was used to drive the extractor rotor. Heat exchangers (E) were used to adjust the temperature of the liquids entering and leaving, while thermometer wells (F) and pressure guages (G) were used to measure temperatures and pressures of operation.

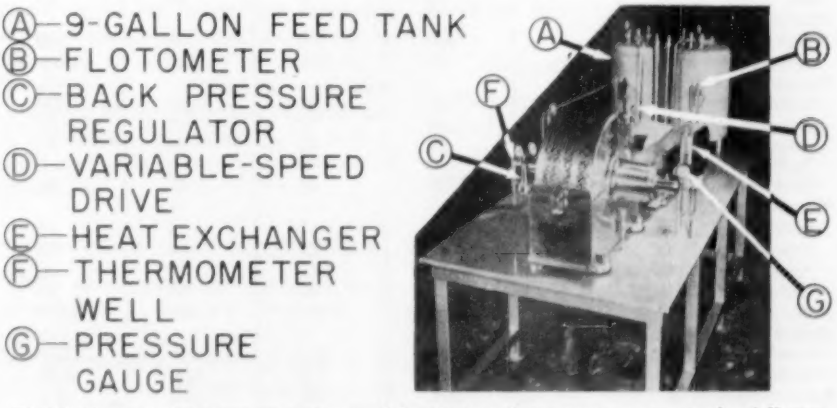

FIGURE 3.—Laboratory extractor used for dephenolizing tests on ammoniacal liquor.

The centrifugal extractor has an 18-in. diameter rotor of 0.25-in. internal width, contains 17 contacting elements, and has a volumetric holdup of approximately 650 cc. A more detailed description of the laboratory machine and its characteristics of operation have been presented by Barson and Beyer (6). These authors determined the stage equivalents of the laboratory extractor to be between 7 and 8 based on the system boric acid-isoamyl alcohol-water. On the manufacturer's standard test system (butylamine-kerosene-water) the laboratory machine developed between 10 and 11 stages. It was felt that the ammoniacal liquor-phenols-light oil system is quite similar in behavior to the butylamine-kerosene-water system and the results obtained on dephenolizing closely correlated stage requirements for the two systems.

Data from Laboratory Extractor

Typical data from several ammoniacal liquor sources are given in Table I. Feed liquor containing 1,950 p.p.m. phenols was reduced to 3.2 p.p.m. in the raffinate at a solvent-to-liquor ratio of 1:1, while at 2:1 solvent-to-liquor ratio only 0.8 p.p.m. phenols remained in the raffinate. All runs were made at a rotor speed of 5,100 r.p.m., which corresponded to a light liquid inlet pressure of 100 p.s.i.g. The raffinate left the extractor at 0 lb. pressure, while 25 to 45 p.s.i.g. was maintained on the extract leaving. Both the extract and raffinate liquids were centrifugally clarified to the brilliance of distilled water. It should be noted particularly that the duration of the test runs at various solvent ratios was 20 min. This is possible only in centrifugal contactors, where the throughput capacity to volume holdup is large; thus the machines are able to reach equilibrium conditions in a relatively short time.

These phenomenal extraction results aroused the interest of several steel companies, and it was suggested that further pilot-plant testing be carried out on "slip" streams of ammoniacal liquors, preferably on 36-in. diameter

TABLE I.—Dephenolizing Data from Laboratory Extractor

Item	Run No.			
	1	2	3	4
Time (min.)	20	20	20	20
Flow rate (cc./min.)				
Light oil	200	140	100	400
Ammoniacal liquor	100	140	200	100
Pressure (p. s. i. g.):				
Light oil, in	100	100	100	100
Extract, out	30	40	45	25
Ammoniacal liquor, in	32	42	47	27
Raffinate, out	0	0	0	0
Back pressure (%)	30	40	45	25
Temperature (°C.):				
Light oil, in	16	17	18	18
Extract, out	22	22	24	28
Ammoniacal liquor, in	16	17	18	18
Raffinate, out	28	31	30	30
Rotor speed (r.p.m.)	5,100	5,100	5,100	5,100
Phenol concentration (p.p.m.):				
Feed	1,950	1,950	1,950	1,950
Raffinate	0.8	3.2	32.0	0.36
Solvent-liquor ratio	2:1	1:1	1:2	4:1

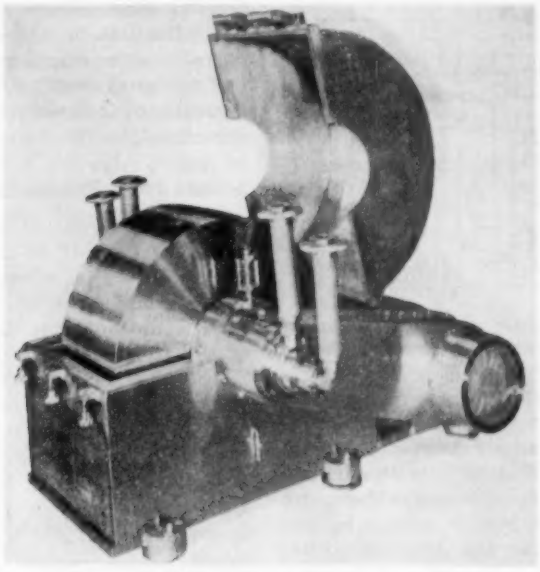

FIGURE 4.—Prototype (36-in. diameter) of production-size extractors.

prototypes of production machines similar to those already employed successfully in the petroleum, petrochemical, chemical and antibiotic industries. Accordingly, the author's company entered into a cooperative program with several steel and coke oven companies.

The important factors to be investigated in pilot-plant operations were long periods of operation (weeks), as compared to relatively short periods of operation in the laboratory extractor. It was also considered important to determine the effect of tar build-up in the light oil, as well as the resistance of 316 stainless steel to corrosion, and to investigate any build-up of carbonaceous materials over long periods of operation.

Description of 36-in. Prototype

The 36-in. extractor used for long-time testing is shown in Figure 4. Its construction is substantially as described, except it is twice as large in diameter (36-in.) as the laboratory extractor. The width of the 36-in. diameter machine was so chosen as to give a throughput capacity in terms of ammoniacal liquor and light oil of approximately 2 to 2.5 g.p.m. of combined streams. The holdup of the rotor was approximately 2 gal. This machine is a "slice" from 36-in. diameter production machines and obviates the necessity of extrapolating R. D. E. T. S.* from an 18-in. rotor spinning at 5,100 r.p.m. to the commercial 36-in. diameter machines spinning at 2,000 r.p.m.

Dephenolizing Flow Sheet

Two of the pilot plants installed included: (a) a dephenolizing extractor for the removal of phenol from the ammoniacal liquors; and (b) a second centrifugal countercurrent contactor for caustic treating the light oil, as illustrated in Figure 5.

* R. D. E. T. S. (Radial Distance Equivalent to Theoretical Stage) is a term applied to centrifugal extractor design, comprising the empirically related factors of radius and r.p.m. (G's); orifice size and pattern; and liquid densities, velocities, viscosities and surface tensions.

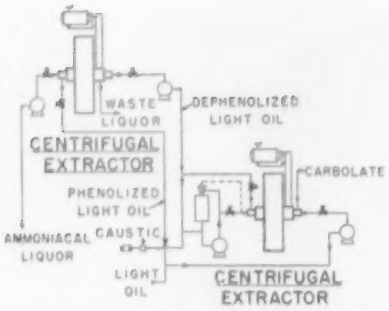

FIGURE 5.—Flow sheet for continuous dephenolizing and treating with caustic.

Both extractors or contactors were driven with variable-speed drives to provide maximum flexibility in operation. The feed liquids were pumped to the machines by suitable pumps, equipped with rotary seals. In one plant, operation was semi-automatic; the others were equipped with flow and ratio control instruments on graphic-type panels.

The ammoniacal feed liquor was furnished by "slip" streams from actual plant operations. Three-shift schedules were arranged so that the pilot plants could be operated continuously.

Although Figure 5 shows the caustic treating step, this paper does not include the data on the caustic treating operations, as considerable additional testing is necessary to establish the behavior of recirculated light oil as it accumulates tar.

Data from Production Extractor

Data on dephenolizing operations from one type of 36-in. diameter extractor have been released by one steel company and are presented in Table II. It is significant that the performance of the 36-in. diameter machine correlates quite closely with the data obtained from the laboratory extractor. The material balance figures are good, considering the accuracy limits of analyses of the feed, solvent, extract and raffinate streams. The liquor ran approximately 1,300 p.p.m., with residual phenol content of 1.1 to 5.0 p.p.m., depending on the solvent ratio used. Temperature of the feed liquor was approximately 56° C., or that corresponding to plant operations.

Discussion

The solvent-to-liquor ratios used for the tests have been plotted *versus*

TABLE II.—Dephenolizing Data from Production-Size Extractor

Item	Run Number							
	803A	803B	803C	807A	807B	810A	810B	810C
Oil-liquor ratio	1.0	2.13	4.05	2.10	3.89	0.99	2.03	3.86
Flow (g.p.m.):								
Liquor	0.664	0.443	0.279	0.47	0.30	0.64	0.51	0.32
Oil	0.661	0.943	1.13	0.99	1.14	0.63	1.03	1.23
Concentration (p.p.m.)								
Liquor, in	1,280	1,328	1,352	1,256	1,305	1,313	1,338	1,330
Liquor, out	5.0	1.6	1.1	3.9	1.1	3.0	1.1	1.2
Oil, in	16.3	6.0	4.7	16	7.8	9.3	12.4	10.3
Oil, out	1,280	656	344	624	344	1,494	688	368
Phenol balance (mg./l.):								
Liquor, in	1,280	1,328	1,352	1,256	1,305	1,313	1,338	1,330
Oil, in	16	13	19	34	30	9	25	40
Total	1,296	1,341	1,371	1,290	1,335	1,322	1,363	1,370
Liquor, out	5.0	1.6	1.1	3.9	1.1	3.0	1.1	1.2
Oil, out	1,280	1,397	1,393	1,310	1,340	1,475	1,397	1,420
Total	1,285	1,399	1,394	1,314	1,341	1,478	1,398	1,421
Recovery (%)	99.1	104.3	101.7	101.8	100.4	111.5	102.6	103.7

p.p.m. phenol in the raffinate (Figure 6). It is interesting to note that the curve begins to flatten out at about a 1.5:1 solvent-to-liquor ratio and that increased solvent ratios do not reduce the residual phenol. At a distribution coefficient of 3:1 the equilibrium between phenol in the light oil entering, and the raffinate leaving at 1.25:1 ratio is near theoretical extraction in the countercurrent multistage machine if the phenol content of the solvent is maintained at 10 p.p.m. or less.

It would appear from the test data on the two different size machines that the 36-in. diameter prototype operating at 2,000 r.p.m. gives substantially the same performance as the 18-in. diameter laboratory extractor operating at 5,100 r.p.m.

The 36-in. diameter prototype machines have been in operation for an average of 6 months. During this period none of the machines required maintenance. Several have been dismantled after completing the test runs; inspection showed no corrosion from materials processed, or any carbonaceous deposits. Simple periodic flushing operations were carried out at the end of each test run, and it appears that this is all that would be required for production-size machines.

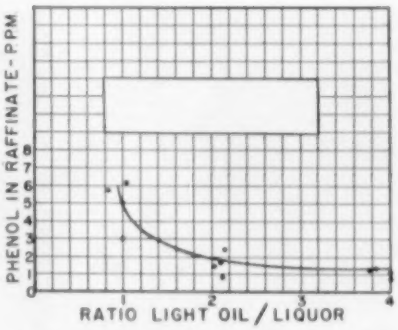

FIGURE 6.—Dephenolizing data from production-type extractor.

Extrapolation to Production-Size Extractors

Typical of production-size extractors used in the petroleum industry is the type shown in Figure 7. This machine has a rotor 36 in. in diameter by 40 in. wide and a rotor holdup of approxi-

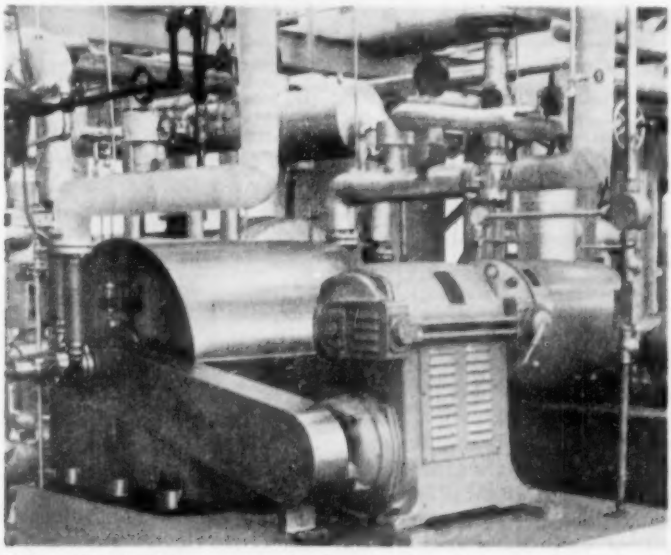

FIGURE 7.—Production-size centrifugal extractor used in the petroleum industry.

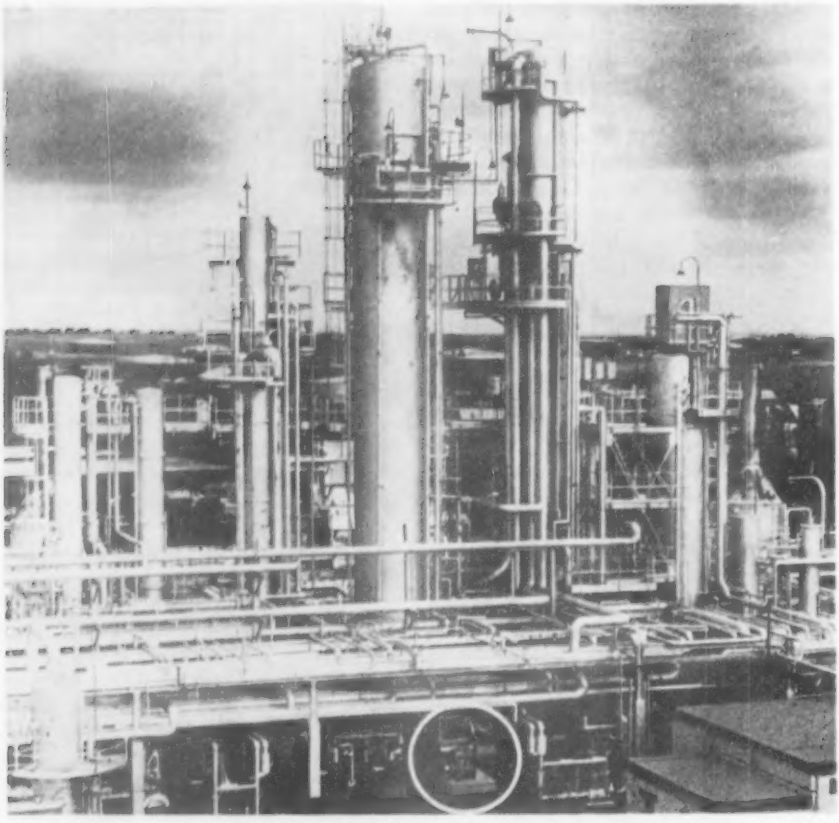

FIGURE 8.—Comparison of size of centrifugal extractor (in circle) and column extractor it replaces.

mately 200 gal. It has a combined capacity of 16,000 g.p.h. on the system lube oil-phenol. On the less viscous system ammoniacal liquor-phenols-light oil this same machine would have a combined throughput capacity of 20,000 g.p.h.

Its design capacity and efficiency, however, were extrapolated from data obtained on the laboratory extractor operating on the same crude stocks being fed to the large extractor. It is equivalent in efficiency to a column approximately 70 ft. high, and has a capacity equal to that of a column 7 ft. in diameter. The size of the centrifugal extractor and the column it replaces is compared in Figure 8.

Although the factor for extrapolation from the laboratory machine to the production-size machine was of the order of 2,500, the extrapolation of the 36-in. diameter prototype to larger capacity machines involves only a simple extrapolation of width. Thus, production-size machines can be guaranteed to produce the same efficiencies as their 36-in. diameter prototypes.

Advantages of Centrifugal Extractors

Production-size extractors (Figures 7 and 8) have high throughput capacity for small volume holdup. Thus, they can be economically constructed

of type 316 stainless steel to withstand corrosion of the process liquids as well as the corrosive atmosphere usually encountered in coke oven operations. It is expected that an extractor of type 316 stainless steel would outlast two columns of ordinary steel construction.

The cost of centrifugal extractors is about the same as columns of the same throughput capacity and stage efficiency, but they have a decided advantage because of their small solvent holdup. Plants employing expensive solvents could start up on a considerably reduced solvent inventory.

The machines are compact and can easily be installed on low concrete foundations, much the same as a pump with its drive motor, at only a fraction of the cost of column erection.

Maintenance on the commercial-size machines, as verified in a number of diversified industries, is extremely low. The 6-month operation on 36-in. diameter machines required no maintenance of hydraulically balanced seals, or the oil-lubricated rotor bearings. It is expected that these machines will continue to run for more than a year without so much as seal adjustments.

Centrifugal force up to 2,000 G's in commercial machines stabilizes operations, eliminates disturbances from emulsion tendencies, produces centrifugally clarified extract and raffinate and makes possible continuous, fully automatic operation.

Power consumption is about of the same order of magnitude as that required for column operations—the operating heads being comparable. Because of high inertia of the rotor, starting requires the use of a 20-h.p. drive on the 20,000-g.p.h. machine; however, once up to operating speed only a 7- to 8-hp. motor is required to keep it spinning.

Centrifugal extractors simply can be flushed or steamed periodically to remove any tar or sludge build-up, thus minimizing the man-hours usually required for cleaning packed columns.

Conclusions

It has been shown by test, both on laboratory and 36-in. diameter prototypes of production machines, that centrifugal extractors can effectively remove phenols from waste ammoniacal liquors containing up to 2,000 p.p.m. to residual phenol contents in the raffinate of 5 p.p.m. and less. With dephenolized light oil of 10 p.p.m. or less phenols, and an oil-to-liquor ratio of 1½: 1, a residual of only 3.3 p.p.m. remains in the raffinate from 36-in. diameter machines.

Production-size machines of 20,000 g.p.h., of the type already in use in the petroleum industry, are available for dephenolizing operations. Their design can be extrapolated and performance guaranteed on the basis of operation of the 36-in. prototype ("slice" off production machines) on plant liquors and light oil solvents.

On the same basis of throughput capacity and extraction efficiency, the centrifugal extractor holdup is only 1/100 that of a column. Because of this small inventory the use of expensive solvents having higher selectivity to phenols, within the practical miscibility limit, now becomes economically feasible. Further, a simple stripping operation to purify the solvent should at the same time economically produce a salable tar acid.

Acknowledgments

Acknowledgment is given W. J. Podbielniak, Mrs. W. G. Podbielniak, and C. M. Doyle, of Podbielniak, Inc., without whose help this study would not have been possible; to G. J. Ziegenhorn and W. T. Sullivan, chemical engineers, who assisted the author in laboratory and pilot-plant operations; and to the chemists and engineers of the several steel companies who, for the present, prefer to remain anonymous.

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CHEMICAL INDUSTRY SPENDING $2.73 BILLION ON NEW CONSTRUCTION, MCA SURVEY SHOWS

The chemical industry completed privately financed construction projects representing an investment of more than $1,216,000,000 during the 12 months ending October 31, 1954, and had under construction or definitely planned another $1,514,000,000, according to a survey of chemical industry expansion announced recently by the Manufacturing Chemists' Association.

The survey covered more than 570 non-government financed projects of the industry, 215 of which were completed between November 1, 1953 and October 31, 1954. Some 219 projects are now being built at an estimated total cost of $933,000,000 the survey showed, and another 138 projects, to be built at an estimated cost of $581,000,000, have been definitely committed.

The total of projects completed during 1954, and those under construction or planned, most of which will be completed within three years, is $2,730,000,000. The MCA pointed out that many more projects have been announced as under consideration or in the planning stage, and that while many of these will be started in 1955, none of them was included in this survey.

Despite some reported cutbacks in construction plans earlier in 1954, the survey appears to bear out the prediction that the chemical industry will quadruple its production capacity by 1975.

In addition to this privately financed construction, the MCA reported that there is an estimated total of some $3,360,000,000 of government-financed chemical construction underway or planned, most of it under contract with chemical companies. This construction, which includes a number of AEC contracts, takes in projects underway which started three years ago and some which will not be completed before late 1956.

Chemical construction projects were reported in 43 of the 48 states. All geographical areas were represented, with the south and southwest showing the greatest expansion.

The MCA survey differs from government and other statistics in two important respects, and therefore cannot be accurately related to these figures. First, instead of calculating money spent on construction in any given period, it classifies projects by those completed, now under construction, or definitely planned.

Second, unlike government statistics, which are classified according to the main product lines of corporations, the MCA survey includes chemical facilities regardless of the main business of the builder. Therefore, it takes into account the large chemical investments being made by the rubber, petroleum, steel, pulp and paper, and other types of companies.

Stream Pollution

AQUATIC LIFE WATER QUALITY CRITERIA

First Progress Report *

AQUATIC LIFE ADVISORY COMMITTEE OF THE OHIO RIVER VALLEY WATER SANITATION COMMISSION

Cincinnati, Ohio

FOREWORD AND ACKNOWLEDGMENT

Early in 1952 a group of biologists and fisheries scientists was invited to act as an Aquatic Life Advisory Committee to the Ohio River Valley Water Sanitation Commission. One of the important concerns of the Commission was to secure an authoritative and practical definition of what constitutes "waters . . . capable of maintaining fish and other aquatic life," a statement finding expression in the compact for pollution control that had been ratified by the states of Illinois, Indiana, Ohio, Pennsylvania, New York, Virginia, West Virginia, and Kentucky. The Commission was not satisfied that criteria of water quality with regard to aquatic life had been adequately formulated for administrative purposes.

Following two years of study the committee has now presented its first formal report, embodying in one document viewpoints and recommendations, some of which had been discussed previously only within the Commission and its industry and research advisory committees. The importance and usefulness of the committee's activities—which are described as "a pioneering effort of applied biology in the field of water pollution abatement"—led the Commission to authorize publication of the report.

Membership of the committee was based on the recommendations of O. Lloyd Meehean, who represents the U. S. Department of Interior on the Commission and is Assistant to the Director of the Fish and Wildlife Service, and who was requested by the Commission to make such recommendations. How well he applied himself to the task is revealed by the roster of the committee, whose members are contributing their efforts to the work of the Commission as a public service. Dr. Meehean serves as Commission-liaison member of the committee; John E. Kinney, formerly of the Commission staff, served as secretary.

The committee is composed of the following:

L. L. Smith, Jr., Department of Entomology and Economic Zoology, University of Minnesota, *Chairman.*

B. G. Anderson, Head Department of Zoology and Entomology, The Pennsylvania State University.

W. A. Chipman, Chief, Special Shellfishery Investigations, U. S. Fish and Wildlife Service.

Theodore Olson, School of Public Health, University of Minnesota.

Edward Schneberger, Superintendent, Fish Management Division, Wisconsin Conservation Commission.

W. A. Spoor, Department of Zoology, University of Cincinnati and Stone Institute of Hydrobiology.

C. M. Tarzwell, Chief, Biology Section, Robert A. Taft Sanitary Engineering Center, USPHS.

In making the report available for publication the Commission wishes to acknowledge with gratitude the efforts of the Aquatic Life Advisory Committee in providing guidance for its deliberations.

EDWARD J. CLEARY,
Executive Director and
Chief Engineer, ORSANCO

* Submitted to the Ohio River Valley Water Sanitation Commission, September 1, 1954.

Formation and Scope of Committee

The Ohio River Valley Water Sanitation Commission was formed to deal with the problems of pollution abatement in the waters of the Ohio River district and to protect all water uses in proportion to their importance to the people and the industries of the valley. Among the more important uses of water are provision of potable water for municipal water systems, process and cooling water for industry, water for agricultural use, water for the production of a harvestable fish crop, and water for general recreational purposes. Although water quality standards for domestic, industrial and agricultural use are fairly well defined, requirements of water for production of fish are poorly understood. Quality standards set up by various regulatory agencies lack uniformity and are for the most part based on an inadequate background of scientific investigation and knowledge of specific water problems. Recognizing these facts the Ohio River Valley Water Sanitation Commission early in 1952 invited a group of aquatic biologists and fisheries scientists to form an Aquatic Life Advisory Committee to assist the Commission in the formation of rational criteria for water quality with reference to the production of fish crops.

The functions of this committee are purely advisory and in no way connected with enforcement of specific regulations or determination of proper water use in particular parts of the water system. All committee recommendations are transmitted to the Commission for consideration and to be acted upon in whatever manner the Commission sees fit. It is intended that the committee integrate the work of industrial committees and the Kettering Laboratory with its own insofar as problems of fish life are concerned.

Policy of Committee

The formation of this committee marks the beginning of a pioneering effort of applied biology in the field of pollution abatement. Therefore, a clearly defined statement of committee policy with reference to its scope of action and limitations on its recommendations is essential. It must be pointed out that life processes are very complex and in many instances there are large gaps in existing knowledge of aquatic biology. Applied biology in pollution abatement is also a relatively new undertaking, with few biologists working in this field. Since biology is a complex science, it must be recognized that there are many factors, slight variations of which may change a situation completely. It is for this reason that hard and fast rules for quality criteria or standards are often impractical and unworkable. The committee believes that the soundest approach to the solution of these biological problems is to study each problem individually, weighing the many factors involved with reference to subsequent water use.

In view of these considerations and many others not enumerated, the committee feels it advisable to work within the scope of the following statement of policy:

> It shall be the policy of the Aquatic Life Advisory Committee to assist the Commission in the improvement of the Ohio River and its tributaries by offering the best possible recommendations on water quality criteria essential for the maintenance of suitable fish habitats as defined by the committee. Such recommendations shall be offered only after the committee has had an opportunity to review the existing data on each specific problem. The committee shall also point out the need for further facts and suggest research projects to obtain such facts. To a large extent the committee will base its evaluation of toxic wastes on bioassays.

Within the scope of this policy the committee has several clearly outlined objectives. First, and perhaps the most important, is to define in general terms what is meant by water suitable for fish life. There is lack of agreement on a proper definition among sanitary engineers, industrial engi-

neers, fishery scientists, and fishermen. Obviously, until a decision is reached progress toward attainment of suitable water quality cannot be made. Second, available knowledge applicable to problems of maintenance of waters suitable for fish life must be evaluated with reference to completeness and adequacy. Third, gaps in scientific knowledge must be pointed out and suggestions for future research to fill these deficiencies proposed. Lastly, because bioassay appears to be the most useful method for the determination of water suitability where pollutants are complex and natural waters are variable, acceptable standard procedures and criteria for the application of results from these tests must be established. When available data on specific problems are adequate, the committee will make recommendations for particular ions or compounds which will be applicable to the local conditions.

It is not within the purview of this committee to make recommendations on the preferred water use in any locality, the relative importance of fish life in any particular region, or the equitable distribution of water-use privileges for any purpose among various units of an industry, municipalities, or the general public.

Meaning of Water Quality Suitable for Fish Life

An understanding of what constitutes water suitable for fish life is not general, even among those most interested in conservation. Most of the critical data available on the effects of various materials on fish have of necessity been limited to observations on the immediate effects as defined by lethality in short periods of time. Toxicity studies have usually been limited to tests of solutions of single ions or compounds and there has been little critical appraisal of toxicity of mixtures of ions or compounds. Water containing pollutants has usually been considered adequate for fish life if no obvious and acute mortality could be traced to known deleterious materials in the water.

A realistic approach to the problems of water suitability for fish life should recognize the fact that fish are an aquatic crop measurable in terms of pounds per acre per year. When a water does not produce a normal annual fish crop because there are pollutants present, even though no mortality has been observed, it cannot be considered adequate. This approach is new to many working in the technical phases of pollution abatement and is not generally appreciated by the public.

Water suitability must also be measured in terms of the species which can be produced. If pollution results in a changed habitat which can produce a large crop of undesirable species but which prevents the growth of a suitable annual crop of desirable species, it is inadequate from the standpoint of fish use. Another condition should be recognized in the consideration of factors which make a suitable fish habitat. It is an established fact that some fertilization by domestic or certain organic industrial wastes may raise fish-producing capacity of waters while at the same time impairing their use for other purming.

In view of the factors outlined, the committee has adopted the following statement defining water suitable for fish life:

> For the purpose of the Aquatic Life Advisory Committee, waters suitable for maintaining fish and other aquatic life are defined as those which produce a satisfactory fish crop as determined by quality of fish flesh, fish yield in pounds per acre, catch per man hour, species composition, and standing populations.

Materials that cause pollution and may affect the capabilities of maintaining satisfactory conditions in waters as above described may be classified as (a) inert materials, (b) oxygen-consuming materials, and (c) toxic ma-

terials. It must be recognized that there is probably no single body of water in any populated area that does not receive domestic or industrial wastes of some type. The fish crop represents the end product of all of the biological processes in the aquatic habitat and is the only single group of animals that offers a variety of interests to man. If a satisfactory fish crop is produced, it may be considered that there are sufficient favorable factors at work to allow waters to be judged satisfactory for the important forms of aquatic life. Since the productivity of natural waters varies from area to area, a standard of productivity will, of necessity, have to be established for each water or portion thereof in question. The standard must have characteristics allowing it to be considered average and normal for the area.

Development of Water Quality Criteria

The development of water quality criteria must take cognizance of a wide range of interests. Industries, municipal water supplies, recreational facilities, and suitable fish habitats all have their particular requirements. Water suitable for one use is not necessarily suitable for other uses. The only course open to regulatory agencies and administrators is to determine, if possible, the optimum water quality for each use, and the relative importance of each use; then set up criteria of quality which will accomplish maximum benefits for all uses in accordance with their importance and within the scope of practical economic procedure.

Up to the present several basic criteria have been used by sanitary engineers to test the necessity for pollution abatement and the efficacy of the various methods of control. First among these has been the existence of conditions which were suitable for human health, usually judged on the basis of bacterial counts, tastes, odors, and heavy metal content. The second important consideration has been reduction of biochemical oxygen demand in sewage effluents to the lowest possible levels. A third consideration which has been important in areas where recreational and commercial fishing is carried on is the acute toxicity of certain wastes to fish. Recently, attention has been given to the effects of certain chemicals on human health and industrial processes. Criteria have usually been based on the quality of effluents rather than on the resultant quality of the receiving waters, and have ignored the antagonism and synergism which may exist in the receiving waters. Long-range effects on production of aquatic life and harvestable fish crops have been overlooked as unimportant or beyond the scope of the engineer and regulatory agency.

Since most states have agencies charged with maintenance of suitable water quality, many attempts have been made to set up absolute criteria in terms of parts per million of particular wastes. These criteria have been general in their application and based on inadequate data concerning the ability of natural waters to absorb varying quantities of pollutants safely according to their location and natural chemical qualities. The combined effect of pollutants has usually also been overlooked in these standards. Although the deficiencies of these standards are generally understood by those who employ them, public demand and administrative necessity will continue their use until a more adequate basis for judgment is procured. In the meantime, active administrative agencies such as the Commission are seeking bases for standards which will be realistic, attainable, and enforceable.

Evaluation of Literature

It is generally accepted that criteria of water quality must be based on the

best scientific data available. However, the literature is large and is often contradictory. The experiments and observations cover a wide range of materials, but there are tremendous gaps in the scientific knowledge. It is therefore apparent that establishment of new water quality criteria can be made only after a thorough search of the existing literature has been accomplished and the available scientific data are evaluated in the light of present requirements. In response to this need, various organizations have instituted programs of literature search and evaluation. Within the scope of the Commission, several of the industrial committees and the Kettering Laboratory have engaged in this work. In recognition of the magnitude of the task and the nature of progress already made, the Aquatic Life Advisory Committee has prepared a recommendation for further procedure on this problem.

During the past several years personnel of the Biology Section, Robert A. Taft Sanitary Engineering Center, USPHS, have made extensive searches of the literature on the toxicity of various substances to fish. The first and second reviews of Doudoroff and Katz (1)(2) have already been published; their review dealing with cyanides and other inorganic substances is expected to be published shortly. These authors expect to complete their series of reviews by 1960 if the schedule which has been set can be maintained. The actual time consumed in producing these reviews will have been the better part of a decade.

Because the critical evaluation of the literature will take more time and effort than the members of the ALA Committee are free to devote to such studies, and in order to produce results in the immediate future, it is recommended that:

1. The Aquatic Life Advisory Committee use the reviews of Doudoroff and Katz as a general basis for their evaluation of existing scientific information, taking note of gaps in scientific knowledge and appraising their evaluation; use these reviews as a basis for establishing water quality criteria where coverage justifies such use; and use these reviews as a basis for recommending areas where further research is necessary.

2. A program of aid to Doudoroff and Katz be sponsored to speed up the completion of the review of the literature on toxicity. By furnishing these investigators with aid in the form of three persons (two should be qualified in the field of aquatic biology, physiology, and chemistry and the third as secretary) the time necessary for completion could be cut to two years.

3. The present literature search being conducted by industry committees and evaluations by Kettering Laboratories be continued to broaden the base of the search, provide another point of view on literature appraisal, and provide abstracts on literature not in the field covered by Doudoroff and Katz.

General Approach to Setting of Criteria

In the setting of water quality criteria the committee believes that attention should be given primarily to the condition of the stream after it has received the pollutant rather than to the nature of the individual effluents which empty into it. After suitable stream conditions have been determined, the various effluents can be adjusted to maintain the desired stream quality. The problems and difficulties which will be encountered in this type of approach are not minimized, but any other will fail to achieve the end sought. Since producing an effluent which will not kill fish when acting alone is no guarantee that this material when combined with others already in the stream will not prove harmful, final condition of the stream will be the basis of evaluation. It is realized that much work must be done on each local

problem to determine the exact amounts of material which can be placed in a stream at various levels of water flow before final requirements for individual pollutors can be made. To accomplish prompt results, the committee believes that minimum requirements should be set at a level where the effluent after it enters the river has no acute toxicity to fish or measurable deleterious effect on aquatic organisms as measured by bioassay.

Because the toxicity of most materials varies with the quantity and type of other materials in the waste and with the nature of the receiving water, it is considered to be impractical in most cases to set standards in terms of parts per million. The committee therefore recommends that water quality criteria be established in terms of bioassay carried on in accordance with standard procedures approved by the committee.

Dissolved Oxygen Requirements

At the outset it should be pointed out that the minimum dissolved oxygen level proposed herein is that deemed suitable for the maintenance of a normal population of warm-water game and pan fishes, and of the forage fishes associated with them. It is not to be regarded as suitable for game fishes of the family *Salmonidae*.

Dissolved oxygen in a body of water under natural conditions is derived from the atmosphere or from the photosynthetic activity of plants. The amount of oxygen that can be held in solution varies inversely with the salt content and the temperature of the water. While the effect of salts at concentrations tolerated by fresh-water fishes is negligible, the effect of temperature is so great that at 86° F. the solubility of oxygen in water is little more than half that at 32° F. Variations in photosynthetic rate and temperature can cause the oxygen content of a body of water to fluctuate considerably, but the magnitude of these fluctuations is increased by the steady removal of oxygen by aquatic animals, and by the oxygen requirements of aquatic plants at night. A succession of sunny days in warm weather may increase the algal population markedly, and when such a period is followed by cloudy weather, the algae may further deplete the oxygen supply. If the water is polluted by substances that contribute to the removal of oxygen through the action of bacteria on them, the magnitude of the fluctuations in the dissolved oxygen concentration may be still greater. An accumulation of the effects of these factors may cause the oxygen content of a stream to vary over a range of 20 p.p.m. or more during a 24-hr. period.

It is known that when other conditions are favorable certain species of fish can survive for short periods of time at dissolved oxygen concentrations as low as 1 to 2 p.p.m. There is evidence, however, that many important species cannot survive at this level. An increase in metabolic rate caused by muscular activity greater than that of the resting level or by an increase in the temperature of the water will increase the demand for oxygen, and it is doubtful that the supply available at these concentrations would be adequate. At oxygen levels as low as 1 to 2 p.p.m. a fish is less able to withstand the effects of other solutes that might interfere with the diffusion of oxygen into the blood. An increase in the carbon dioxide content of the water or, under some circumstances, a lowering of the pH will lessen the animal's ability to extract oxygen. The presence of heavy metals imposes an additional burden on the respiratory mechanism because it coagulates a film of mucus over the gills that makes oxygen penetration more difficult. At low oxygen concentrations a fish may die under such conditions whereas at higher concentrations it could survive. Intensive studies conducted over a period of 14 months by the USPHS on

Lytle Creek, a small stream near Cincinnati, Ohio, where the fish population may be considered representative of those in the Ohio Basin, showed that a well-rounded fish population occurred only in those portions of the stream where oxygen levels did not fall below 3 p.p.m.

In the upper recovery zone, where minimum dissolved oxygen was between 1.0 and 1.6 p.p.m., fish were usually absent. In the lower recovery zone, where minimum dissolved oxygen was from 1.6 to 2.0 p.p.m., an abundance of rough fishes occurred.

In view of the foregoing facts, recommendations for suitable dissolved oxygen levels must take the following considerations into account:

1. The minimal oxygen requirements of the fish.

2. The necessary margin of safety required to allow for activity, increased body temperature, increased carbon dioxide, lowered pH, and the presence of toxic substances.

3. The fact that a fish may tolerate a low oxygen concentration for a few hours, but will not thrive if this level is maintained indefinitely.

4. A well-rounded fish population does not occur in areas where the oxygen content falls below 3 p.p.m. and a coarse fish population does not occur when the oxygen concentration falls below 2 p.p.m.

5. The quantity of dissolved oxygen in natural waters may fluctuate over a wide range.

6. A fall in the oxygen concentration to an anoxial level, even for a short time, or infrequently, may destroy the fishing potential of a stream, if not the entire fish population.

7. The recommendation of an average value for dissolved oxygen would not set the critical lower limit on the permissible oxygen level.

The Aquatic Life Advisory Committee recommends, therefore, that until future research indicates that a reconsideration is desirable the minimum permissible oxygen concentration for a well-rounded warm water fish population shall be as follows:

> The dissolved oxygen content of warm-water fish habitats shall be not less than 5 p.p.m. during at least 16 hr. of any 24-hr. period. It may be less than 5 p.p.m. for a period not to exceed 8 hr. within any 24-hr. period, but at no time shall the oxygen content be less than 3 p.p.m. To sustain a coarse fish population the dissolved oxygen concentration may be less than 5 p.p.m. for a period of not more than 8 hr. out of any 24-hr. period, but at no time shall the concentration be below 2 p.p.m.

The committee further recommends that dissolved oxygen determinations be made in accordance with the procedures specified in the 10th Edition of "Standard Methods" (3).

Oxygen concentrations are expressed as parts per million, rather than as percentages of saturation, since the oxygen value expressed by the latter term varies with changes in temperature. Table I illustrates the effect of temperature on the oxygen holding capacity of pure water and the relationship between oxygen content in parts per million and percentage of saturation. At a water temperature of 41° F. (5° C.) a level of 75 per cent of saturation would contain 9.57 p.p.m. dissolved oxygen, whereas at 86° F. (30° C.) the same percentage saturation would be attained with only 5.65 p.p.m. At temperatures of 90° to 96° F., which are not uncommon in the habitats of warm-water fishes, water with 75 per cent of saturation would contain still less dissolved oxygen. It is evident, therefore, that 75 per cent of saturation would represent an ample level at 41° F. but would be barely adequate at 95° F. The marginal adequacy of 75 per cent of saturation at the latter temperature is obvious in view of the fact that the metabolic rates of fish and other aquatic animals increase as the temperature rises.

TABLE I.—Dissolved Oxygen Content of Pure Water at Various Temperatures and at Selected Percentages of Saturation, Expressed in P.P.M.[1]

Temperature		Percentage of Saturation			
(°C.)	(°F.)	25	50	75	100
0	32	3.64	7.29	10.91	14.57
5	41	3.19	6.38	9.57	12.75
10	50	2.82	5.64	8.46	11.27
15	59	2.52	5.04	7.56	10.08
20	68	2.27	4.55	6.83	9.11
25	77	2.07	4.14	6.21	8.28
30	86	1.88	3.77	5.65	7.53
35	95	1.76	3.51	5.27	7.02

[1] Values for "100 per cent of saturation" based on oxygen content of water saturated with air (free of NH_3 and CO_2) at total pressure of 760 mm. Hg (air plus aqueous tension) (4).

It is necessary that sampling for dissolved oxygen be conducted in such a manner that fluctuations in oxygen concentrations are noted. In a polluted stream where there is photosynthetic activity, oxygen levels are usually highest between 2:00 and 4:00 PM, and lowest just before or just after sunrise.

Samples for oxygen determinations, therefore, should include some taken during periods just before and just after sunrise and at any other times likely to be critical (that is, during periods of low water and high temperature, and on cloudy days during periods of exceptionally warm weather).

pH Requirements

Some fishes have been found in certain lakes and streams at pH values as low as 4 and as high as 10 or above. The population present under such extreme conditions is usually limited to a few species and is the result of a long period of acclimatization. Observation and experimental studies indicate that hydrogen-ion concentration probably does not affect fish adversely between pH 5 and pH 9. Some species of fish, and also some age groups, are more sensitive to extremes of pH than are others.

The addition of an acid or an alkali to a stream is likely to affect fish adversely, even though the pH range 5 to 9 is not exceeded. The effects may be *direct*, arising from the nature of the acid or alkali itself, entirely apart from its effect upon pH, or *indirect*, because the pH has an effect upon other solutes in the water. Some materials are more toxic at low pH, whereas others are more toxic at high pH levels.

Direct Effects of Adding Acids

Highly dissociated inorganic acids do not appear to be toxic at pH values above 5. If added in quantities sufficient to lower the pH below 5, however, they are toxic, perhaps because they coagulate mucus over the gills and thereby interfere with the respiratory exchange. Organic acids and poorly dissociated inorganic acids may be toxic at pH values well above 5, either because the anion or molecule is directly toxic itself (for example, hydrocyanic, hydrosulfuric, hypochlorous, tannic, etc.), or because the undissociated acid molecule is able to penetrate the external membranes of the fish and affect the pH of the blood. In the latter case, the acid may affect the CO_2- and O_2-combining power of the blood. It should be noted also that the concentrations of such acids required to lower the pH to 5, especially if the water is buffered, may be heavy. It follows that pH is not a reliable index to pollution by acids, the toxicity of which is due chiefly to the undissociated acid or acid gas.

Indirect Effects of Adding Acids

In very alkaline waters the addition of strong mineral acids may bring about the release of CO_2 in quantities which are harmful to fish life. In polluted waters the foregoing effects will be aggravated by the fact that lowering pH will increase the toxicity

of such pollutants as cyanide and heavy metals. For example, a drop of about 1.5 pH units can cause almost a 1,000-fold increase in the toxicity of a metallo-cyanide complex.

Direct Effects of Adding Alkalies

Highly dissociated inorganic alkalies do not appear to be toxic at pH values below 9. Organic bases and poorly dissociated inorganic bases may be toxic at pH values below 9, however, because the cation or undissociated molecule may be toxic. As with organic and poorly dissociated inorganic acids, the concentration required to change the pH over several units might be rather great. Ammonium hydroxide (NH_4OH), for example, is toxic in concentrations insufficient to raise the pH to 9. Here again pH may not be regarded as a suitable measure of pollution. High pH levels are often produced in fertile waters through the photosynthetic activity of the phytoplankton, which removes CO_2. Because these high levels are of short duration they do not produce the harmful effects of continuous high levels due to strong alkalies.

Indirect Effects of Adding Alkalies

In natural waters the addition of non-toxic alkalies in quantities sufficient to raise the pH to 9 would probably have no indirect effects. In polluted waters, however, the increase in pH may affect the toxicity of such pollutants as ammonia, ammonium hydroxide, ammonium salts, etc.

Other Considerations

It has been observed that the pH of most productive streams falls in the range of 6.5 to 8.5. When the pH falls below 6.5 or rises above 8.5, many of the basic nutrients become tied up so they are unavailable to the plants and the over-all productivity and the production of fish food organisms is lowered. The non-lethal limits of pH are narrower for some fish food organisms than they are for fish. For example, *Daphnia magna* does not survive experimentally in waters having a pH below 6. For these reasons it is apparent that to maintain optimum fish production pH values should be maintained in the range of 6.5 to 8.5.

In view of these considerations, the Aquatic Life Advisory Committee recommends:

1. That pH be recognized as a poor criterion for the expression of toxicity of acids and alkalies in general, and that its use be restricted to the control of the addition of highly dissociated inorganic acids and alkalies known to be non-toxic within the pH range of 5 to 9.
2. That at no time shall acid be added in quantities sufficient to lower the pH below 5, nor alkalies sufficient to raise the pH above 9; and that, insofar as possible, pH values be maintained between 6.5 and 8.5 to maintain the productivity of the water for aquatic life.
3. That the addition of ammonia (as NH_3 or NH_4OH), poorly dissociated inorganic acids, and organic bases and acids shall be regulated not in terms of pH, but in terms of their own toxicities as established by bioassay.

Criteria for Judging Toxicity of Wastes by Bioassay

In the development of pollution abatement programs it would be convenient to have precise standards established for the disposal of industrial wastes. The tasks of both industry and regulatory agencies would be much simpler if such standards could be set. Since the oxygen and pH requirements of many fishes and some other aquatic organisms have been studied intensively, it is possible to recommend criteria pertaining to these factors. Criteria for many substances, however, cannot now be established because the requirements of fishes and other aquatic organisms have not been established quantitatively. Further, such tolerance limits as have been determined for individual waste components are not always applicable to all im-

portant species in all waters and especially to situations where a mixture of chemicals is involved.

Published data on the toxicity of industrial waste components reveal that there is considerable variation in the lethal concentrations of these substances. This fact is not surprising in view of the diversity of waters that have been used as diluents and of organisms used in the experiments described in the literature. The toxicity of many substances varies greatly from one water to the next, depending on the nature and quantities of dissolved materials present. For instance, some waters are highly buffered and are able to neutralize large amounts of acids, whereas others are only slightly buffered and consequently can neutralize little acid. Ammonia is much more toxic in alkaline waters than in neutral and acid waters. On the other hand, cyanides are more toxic in acid waters than in alkaline waters.

Aquatic organisms differ greatly in their susceptibility to toxic substances. For example, fishes of the black bass and sunfish family are more resistant to copper than are trout and many species of the minnow family, whereas the water flea, *Daphnia*, may be more susceptible than any fish species.

Although tolerance limits are known for many materials, little is known of the toxicity of mixtures. Because wastes are usually mixtures and not single substances, the toxicity of the mixture and not the individual components must be considered. The toxicity of such mixtures cannot always be predicted on the basis of the individual toxicities of their components, as in the case where almost equally toxic solutions of copper and zinc salts are combined. The resulting mixture can be much more rapidly fatal to fish than were the component solutions.

In order that wastes may be disposed of in a manner that will leave the receiving water unimpaired biologically, evaluation of their toxicity to organisms in the receiving water is essential. This end can be achieved only through bioassays performed under appropriate experimental conditions.

Procedures for conducting bioassays for the direct evaluation of the toxicity of water pollutants have been prepared by a committee of the Federation of Sewage and Industrial Wastes Associations. The committee's report (5) contains recommendations on the choice and preparation of test animals; the selection and preparation of the experimental water; temperatures; test containers; experimental procedure, reporting, interpreting and use of bioassay results; auxiliary methods; etc. In this report it is recommended that the results of toxicity tests be expressed as median tolerance limits (TL_m). TL_m is the concentration of the substance or waste in question which kills one-half the animals in a specified period of exposure (for example, 48-hr. TL_m). These procedures are now in use in industrial, state, and federal laboratories.

Permissible concentrations of toxicants in waters receiving industrial wastes are those which can be tolerated indefinitely by all individuals (and not only 50 per cent) of all significant species of aquatic organisms, including organisms which serve in the food chains as well as fish and others of direct economic and recreational importance, in all stages of their life history. Therefore, the concentration of toxic industrial wastes should never be more than a small fraction of that concentration which under experimental conditions is demonstrably fatal within a limited period of time to 50 per cent of the test animals used in the bioassay. It is believed that the result of the 48-hr. TL_m multiplied by an application factor of 0.1 represents a concentration of waste which usually will not produce adverse effects on the aquatic organisms as a whole. In some instances more thorough investigations

of the toxicity may reveal that a greater application factor is adequate. However, in other instances a much smaller application factor may be found necessary. Different application factors should be established for different types of wastes depending on their chemical and toxicological properties and the nature of the receiving water. The application factor of 0.1 is indicative of the probable average and, therefore, is tentative and should be modified as conditions demand.

In view of these considerations the Aquatic Life Advisory Committee makes the following recommendations for controlling the disposal of toxic wastes:

1. The toxicity of wastes to aquatic life in the receiving water can most effectively and reliably be determined by means of bioassays.

2. The bioassay methods for the evaluation of acute toxicity of industrial wastes to fish described and recommended by the Committee on Research, Sub-committee on Toxicity, Section III, Federation of Sewage and Industrial Wastes Associations are endorsed.

3. The final concentration of any waste in the receiving water should be no greater than the 48-hr. $TL_m \times 0.1$ (that is, the 48-hr. TL_m as determined by the bioassay methods recommended multiplied by 0.1, the tentative application factor). Other application factors may be used in specific cases, but only after thorough investigations justifying their use have been made.

The Aquatic Life Advisory Committee, in recommending the bioassay method as a practical and applicable method for measuring the toxicity of wastes to aquatic organisms in waters receiving such wastes, recognizes that there are certain limitations to the application of the method which definitely affect interpretation of the results. Consequently, the person or persons attempting to apply bioassays to the problem must use considerable judgment in organizing each test, such as the selection of test animals, etc. Considerable care must be used in the drawing of conclusions to recognize limiting factors in each test. Therefore the committee recommends that bioassays be conducted by persons of recognized experience and training in this field. This recommendation is made for the sole purpose of assuring that the results obtained from bioassay tests be of the highest quality and greatest reliability.

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THE FINAL STEP IN SEWAGE TREATMENT*

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Until 15 years ago it was commonly held that a high nitrate content of a biologically treated sewage effluent was significant of a high degree of purification. Today, however, high nitrates are not always considered desirable. Nitrates are very efficient fertilizers (1) (2) (3), and in receiving waters they may stimulate the growth of aquatic plants in objectionable quantities. The plants pollute the water; they die; and they can form new putrescible and malodorous sludge. An example is a lake in the Wupper region of Germany which was receiving effluent from an efficient trickling filter plant. A similar situation of aquatic plant growth is created by the effluent from the activated sludge plants of Chicago (4).

Under certain circumstances it is also possible that in natural surface waters fertilizing salts are produced by the process of self-purification. These salts establish their presence by objectionable aquatic plant growth far downstream. An example of this condition was reported for the German city of Würzburg (5). At the time, Würzburg, a city of 100,000 population, had no sewage treatment plant with the result that all treatment depended on the self-purification capacity of the River Main. During this period, especially at low water, algae grew in enormous quantities for a distance of 60 mi. downstream. Where the water was dammed up, 75 mi. below the sewer outfall, the decay of dead algae caused a serious fish kill. The conclusion is that the calculation of the load capacity of a stream must sometimes include the effect of the concentration of fertilizing salts.

Maintaining Low Nitrate Content During Treatment

The rule today is to keep the content of nitrates and other fertilizing salts in the treatment plant effluent as low as possible rather than so high.

Sewage sludge has been shown to be the principal source of nitrates. Therefore, it is essential that the sludge formed during biological treatment be separated and withdrawn from the sewage as completely and frequently as possible. This leads to the following obvious requirements:

1. For irrigation areas, efficient primary settling tanks are necessary.
2. Trickling filters must be kept as free of sludge as possible. This can be done by using a high rate of loading per area and recirculating the sewage if necessary.
3. In activated sludge systems the solids content in the aeration tank must not be too high nor the aeration time too long.

Control of Objectionable Aquatic Plant Growth

Many receiving waters are subject to objectionable growths of aquatic plants. The responsible fertilizing salts are contributed to the surface waters not only by sewage and industrial wastes, but also by surface-water drainage from agricultural areas. According to Müller (6), the enormous plant growth in streams and lakes does not

* Translated from *Zeits. des Deutschen Ver. v. Gas-u. Wasserfachmänners* (*GFW*), **95**, 18, 561 (1954) by Werner Stumm, visiting scholar in Sanitary Engineering, Harvard University, Cambridge, Mass.

occur if nitrate as N_2 is kept below 0.3 p.p.m. and the total nitrogen as N_2 is below 0.6 p.p.m. In most cases, however, the nitrogen content is higher, so that it has become general practice to control plant growth through the use of chemicals or other means.

Algae grow rapidly during the summer months in ponds and reservoirs serving as water supplies. Clogged sand filters frequently result as well as taste and odor in the drinking water. The usual method of control is to apply copper sulfate during the early stages of algae growth.

It is also possible to use chlorine for algae control purposes. Kaempffe (7) reported an example of chlorine application in a large collecting ditch draining well-nitrified effluent from the Berlin-Carolinenhöhe irrigation area. Under the influence of sunlight and fertilizing salts the water became covered with masses of floating algae. Decomposition of these growths produced a putrescent mud. It was too expensive to remove the floating algae and the mud. Accordingly, chlorine was used with considerable success during the four summer months of 1952. It was possible to keep the ditch free of algae using only 0.85 p.p.m. of chlorine. The treatment cost was approximately $0.90 per day for the sewage from a population of 100,000. The presence of frogs, small fish, and water beetles indicated that the biological equilibrium had not been seriously disturbed.

The fertilizing effect of the nitrates depends on the phosphate content in the water. Therefore, it is possible that the effects of nitrates can be reduced by keeping the phosphates under control.

Sawyer (8) proposes to coagulate the phosphates in the sewage treatment plant effluents by using iron chloride. According to Owen (9), phosphates also can be precipitated with lime. A critical review of the different possibilities of phosphate removal is given by Lea, Rohlich and Katz (10), who recommended alum as the coagulant. Thomas (11) made an investigation of many over-fertilized Swiss lakes to determine whether or not nitrates or phosphates are the important minimum factor responsible for the enormous growth of algae, and if so, under what conditions. The important role of phosphates also has been pointed out by Ohle (12)(13). Despite the difficulty of drawing definite conclusions, however, it is certainly possible in many cases to minimize the effect of nitrates by reducing to a minimum the phosphate content of the sewage effluent.

Separating Fertilizing Salts from Sewage Effluents

In Germany fertilizing salts are frequently removed from sewage treatment plant effluents by means of spray irrigation. Large areas are required because one acre is needed to handle the daily volume of sewage originating from 12 persons.

This method doubtlessly keeps the receiving waters free from fertilizing salts and provides the irrigated plants with nitrates and phosphates. A disadvantage is that all of the effluent is lost through evaporation and transpiration. This procedure can only be recommended if there is no need for the sewage treatment plant effluent.

Another possibility is the discharge of the treatment plant effluent to large ponds where aquatic plants would be grown and collected regularly. The proposal has been made by Howard (14)(15) to use the floating water hyacinth in sewage ponds of South Africa. This plant grows in enormous quantities in over-fertilized streams of the Southern United States. Calculations based on the climate in South Africa indicate that 445 acres of ponds would be sufficient for the separation of the fertilizing salts from the treated sewage originating daily from a population of 100,000. The collected hya-

cinths can be composted and the resulting humus used for agricultural purposes. One acre of pond would handle the treated wastes from 225 persons. Compared with 12 persons per acre by means of spray irrigation, the result is an important saving in land area.

It is usually necessary to collect and remove the floating aquatic plants. When removal is not practiced and the growth of aquatic plants is enormous floating islands are formed by the agglomerating plants (16).

It is much more difficult to remove the small algae from a pond than the large floating plants. In recent years some research work has been done in the United States and Japan on the cultivation of algae as a food supply. Reports on this work reveal how difficult it is to cultivate certain species of algae and to separate them from the water. Sand filtration of the algae-bearing water has been proposed by Leibee and Smith (17) so that the algae can be obtained by backwashing the filters.

In most cases it is easier to remove the settled mud caused by the death of the algae than to remove the living algae. This must be done before decomposition of the mud affects the dissolved oxygen content of the water. Oxygen depletion from this cause is known to occur in deep Swiss lakes. It does not occur in the shallow artificial lakes of the Ruhr area because the settled mud is regularly washed away by high water, even though these lakes are loaded with sewage to a greater extent than the Swiss lakes.

In artificial ponds, where the water is defertilized by algae, it is necessary from time to time to pump out the mud. The previously mentioned collecting ditch of the Berlin-Carolinenhöhe installation was cleaned in this manner prior to the use of chlorine.

This collecting ditch is 0.684 mi. in length, with an average depth of 3.94 ft. and a width of 24.6 ft., producing a surface area of 2.05 acres and a volume of 274,000 cu. ft. The volume of flow is 26.4 gal. per sec. at a velocity of 2.75 ft. per min., resulting in a 22-hr. detention period. The treated sewage from a population of 100,000 entered the ditch in the summer with 100 p.p.m. of nitrates and no ammonia. After flowing 165 ft. the nitrate content was reduced to 65 p.p.m. Further determinations were not made.

The ditch mud, containing principally decayed algae, analyzed two-thirds sand and one-third iron oxide after ignition. The mud dried within a few days.

This experience may provide some suggestions for special cases where it is desirable to make use of artificial ponds in order to eliminate objectionable fertilizing salts. Based on calculations for the previously described ditch, an acre of water surface is needed for the defertilizing treatment of the treated sewage effluent from a population of 16,200.

If the defertilizing in shallow ponds is used, the detention period should be 1 to 3 days with a sewage loading of 16,000 persons per acre. Pond depth should be not less than 4 ft. in order to prevent the growth of rooted water plants, which must be cut. The high operating costs of this treatment can be reduced by using the ponds only during the summer months when large algae growths are a nuisance. Further investigations are necessary on the nitrate reducing capacity of these ponds.

Conclusions

Sewage can be treated in three steps in accordance with requirements: The first step is mechanical purification in settling tanks; the second, partial biological purification; and the third, complete biological treatment by trickling filters, activated sludge, or irrigation. A fourth step may be added for the removal of fertilizing salts, especially the nitrates.

Two possibilities for this last step in treatment are spray irrigation over large areas or the use of shallow ponds from which the floating aquatic plants and settled mud are removed periodically. Both methods are expensive and require large areas. Spray irrigation also has the disadvantage of water loss.

In Germany this fourth purification step in most cases can be delayed for many years because there is more urgent work to be done in the first three steps. Nevertheless, it is very desirable that the nitrate content of sewage works effluents be kept to a minimum.

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RESEARCH FELLOWSHIPS AVAILABLE AT RUTGERS

Research fellowships in sanitation leading to the M.S. and Ph.D. degrees have been announced for the 1955–6 school year (11 months) by Rutgers University. The fellowships carry stipends commencing at $1,716, plus free tuition for graduate course work.

Application forms and additional information may be obtained from Dr. Harold E. Orford, Department of Sanitation, Rutgers University, New Brunswick, N. J.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

CERTIFICATION EXAMINATIONS

About this time of year the thoughts of many sewage plant operators turn to the forthcoming short schools, conferences, or operator certification examinations. In other instances the operator has just returned from one. He may be inspired; his interest in the profession has been rekindled and once more he has bright aspirations for the future. On the other hand, he may be disgusted with the school or conference or bitter over an examination. The latter is an operator who blithely went off to short school on Monday morning with the thought that he would attend classes, enjoy associating with his fellow operators, and then breeze through the examination for which the short school lectures had prepared him. Even if he had heard that the examinations were "tough," he had deluded himself with the idea that if he paid close attention to the lectures and studied his notes he should be able to gather enough points to slip by on the examinations.

No operator should expect to pass any examination with the material given at the short school alone. The time to learn the material required for an operator's certificate is before the short school. Today an operator must study and learn every day, on the job and at home, so that he is prepared before arriving at the school. This preparation has an excellent psychological effect on the operator. He is not under the tension of having to remember everything the instructor says, because he has to pass an examination, but rather he is open-minded. The courses present, in a new light, material that he has already touched upon or become familiar with. Accordingly he can enter into the class discussions. The result is a better course, for himself, his fellow students, and the instructor.

In his studies an operator should try to understand the "why" and the "how," rather than to rely on memory or a formula. Many men seek to learn formulas for this and formulas for that until their heads are full of formulas. It is easy to learn formulas and very easy to get so many in one's head that they become jumbled together. If the operator learns why and how, the solution to the problems can be reasoned out.

An instructor of many years experience recently stated that the most common errors found on examination papers are those due to mistakes in arithmetic. There now are available a number of good correspondence courses in arithmetic. These may be obtained for nominal fees from the general extension division of some of the state universities. These courses present practical everyday problems dealing particularly with those situations that an operator comes up against. Incidentally, the arithmetic learned can be used in many other types of work.

Self-education is an important step in raising the professional status of the operator. Each of us must work a little harder in this important phase of our professional life. As Spring begins to awaken the earth, let each one resolve to take a more active part.

D. P. S.

SNAILS IN THE TRICKLING FILTER

By George T. Lohmeyer

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Many interesting creatures live in trickling filters and there is no exception at the University of Florida sewage treatment plant (see This Journal, **25**, 9, 1104; Sept., 1953). At Gainesville, Fla., the University operates a modern treatment plant designed for research work while treating the sewage originating from the campus buildings. Both standard and high-rate trickling filters are used to provide flexibility for study purposes.

In spite of identical maintenance on both the 112-ft. standard-rate filter and 40-ft. high-capacity filter, the rotary distributor on the latter frequently stopped turning while the standard-rate distributor rotated perfectly. This limited the source of difficulty to the filter recirculation system. Recirculation is accomplished by lifting the filter effluent into a head box where it mixes with the settled sewage and is discharged to the rotary distributor. Two 300-g.p.m. centrifugal pumps, electrode controlled, accomplish the recirculation.

Probable Trouble

Examination of the mercury seal on the high-capacity filter, after the filter had not been functioning properly, revealed a fine black substance. It was felt that this material might possibly be pulverized snail shells. These could have been washed from the filter, picked up by the recirculation pump, and discharged to the head box, where they passed to the filter, settling in the mercury seal. The finely ground snail shells acted as an abrasive between the rotating and stationary portions of the distributor resulting in a slowing down of the mechanism.

Snails in trickling filters are not uncommon; therefore, it was no mystery that they were present. No problem is created when the filters are loaded as standard-rate filters, because the snails settle out in the secondary clarifiers and are handled the same as the sludge, there being no opportunity for the snails to be returned to the filter influent.

Identity of Snails

The snails have been identified as belonging to the genus *Physa*, a small fresh-water snail which is apparently tolerant of not exactly "fresh-water" conditions. They reach an average length of not quite ¼ in., although this snail is reported to grow larger under other conditions, and lay their eggs within the filter bed.

Remedial Measures

An attempt was made to kill all the snails present in the filter by means of chlorination. All plant influent was diverted to the standard-rate filter. Using the recirculation pumps, the high-rate filter was kept dosed for three days with a chlorine residual of approximately 3 p.p.m.

Following this dosing the filter was thoroughly flushed. Almost a wheelbarrow load of these small snails was removed (Figure 1) from the recirculation pump wet well. However, an unknown quantity of dead snails remained in the filter bed.

The high-capacity filter was then placed back in service and operated without difficulty for a period of eight months before the snail killing operation was performed again. It is possible that reinfestation occurred when, in the course of research studies, efflu-

FIGURE 1.—Wheelbarrow load of small fresh-water snails removed from the recirculation pump wet well following prolonged chlorination of a high-rate filter.

ent from the standard-rate filter was recirculated through the high-capacity filter.

A check with the manufacturer of the rotary distributor did not uncover any reports of a similar experience. The snails seem to be the only logical answer to the improper operation of the distributor. Entry to the mercury seal may have been through a worn seal ring. There is doubt that fine material sluffing off the filter medium (slag) could repeatedly cause stoppage of the rotary distributor.

AUTOMATIC VALVE FOR SLUDGE LINE

What do you do when there is backflow through sludge line check valves? Superintendent A. L. McGee of the Chehalis, Wash., sewage treatment plant was faced with the problem of having raw sludge flow out of the sludge line to the digesters, back into the clarifiers. The result was an overloaded septic condition with scum and gas problems.

To solve the problem, Superintendent McGee made an automatic hydraulic control for the plug valve in his sludge line. A hydraulic cylinder was obtained from a surplus equipment store. Connected to the hydraulic lines of the cylinder were two solenoid valves wired into the time-clock circuit controlling the sludge pump. A lever was fastened to the piston end of the

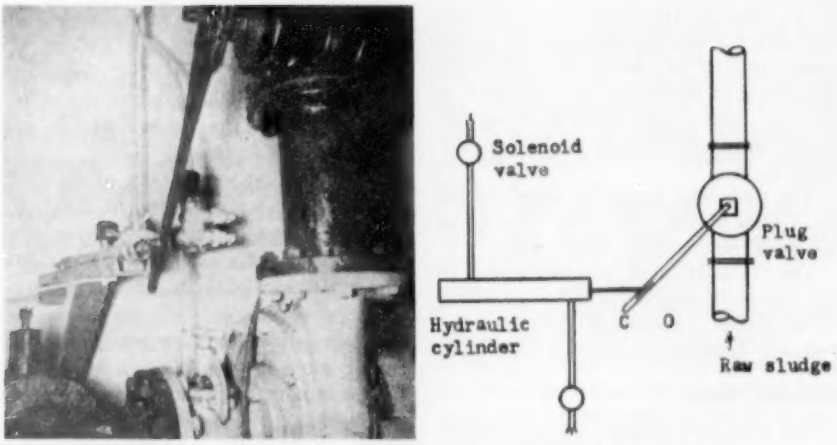

FIGURE 1.—Hydraulic cylinder control for sludge line plug valve.

hydraulic cylinder (Figure 1) to open or close the plug valve when the cylinder was actuated.

Now when the sludge pump starts, the hydraulic cylinder opens the plug valve, and closes it when the pump stops. Total cost was $65; result—no backflow problem.

NOTES FROM A PLANT NEWSLETTER *

August, 1954

The average raw sewage flow pumped was 14.87 m.g.d. during the month of August. Grit removal was 18.4 cu. yd. or 1.08 cu. ft. per million gallons.

Douglas fir, formerly a disposal problem at the rate of 200 tons per day, is now used for plastics.

Maximum daily gas production did not quite reach 200,000 cu. ft. Average daily production was 173,620 cu. ft., having a CO_2 content of 32.5 per cent.

As computed from the sampling and metering of raw sludge drawn from the Little Miami settling tanks in August, an average of 23,600 lb. of dry solids were removed daily from the raw sewage. This is in contrast with a daily removal of 15,100 lb. of solids as calculated from samples of raw sewage and plant effluent analyzed for suspended solids. There is much room for improvement.

What is the minimum safe height for waste gas burners mounted on plant building roofs? When the roof tar coating melts, things may be a little too hot! The roof temperature directly below the burners was 156° F. The roof temperature 30 ft. away from the burners was 122° F. Extensions on the burner stacks will prevent any possibility of fire in the future.

The maximum B.O.D. recorded in August for a daily composite sample of raw sewage was 136 p.p.m.; the average for the month was 104 p.p.m. The average daily removal of B.O.D. was 38.5 per cent.

From theoretical tables developed by

* Extracted from the August, October and December, 1954, issues of "The Settling Tank," newsletter of the Little Miami sewage treatment works, Cincinnati, Ohio, edited by D. P. Backmeyer, Superintendent.

A. L. Genter, the ferric chloride dosing rate for the digested sludge at the plant should be about 2.5 per cent. Satisfactory filtration rates using 3 to 3.5 per cent ferric chloride were recently accomplished on plant-scale operation.

The man who keeps his mind on his work goes ahead. The man who keeps his work on his mind goes crazy.

The volatile acid concentration in the digesters continues to be less than 1,500 p.p.m. Total alkalinity in the primary digesters averages 2,500 p.p.m.

October, 1954

The total raw sewage volume treated at Little Miami in September was 376.16 m.g. The suspended solids of the raw sewage averaged 268 p.p.m. Plant efficiency was indicated by 56.3 per cent removal of suspended solids and 44.1 per cent removal of B.O.D.

Approximately 90 persons, members of the Engineering Society of Cincinnati, and their families, inspected the plant facilities on Friday evening, October 1.

Copper sulfate solution is now being used to prevent mold growth in the wool filter cloths when the filters are not in use for several days.

Approximately 380 persons visited the Little Miami plant on October 13, as part of the Federation Annual Meeting program.

The 5,840-gal. tank car of ferric chloride unloaded on October 4 contained 43.81 per cent ferric chloride. The cost, anhydrous basis, delivered to our siding was $4.07 per 100 lb.

A recording dial indicator with a 10-in. diameter 7-day chart is to be provided for each of the 12 floating covers at Cincinnati's new Mill Creek sewage treatment plant. These dials will continuously record the position of the digester covers.

On October 12, when all the raw sludge was added to the No. 1 digester as part of a series of special loading tests, a total of 164,530 cu. ft. of gas was produced. The production rate for this maximum day was 2.45 cu. ft. of gas per cubic foot of digester capacity in use. There is no top scum problem when the tank contents are cooking at this rate.

A 30-gal. hot water tank at 50 p.s.i. will have a temperature of 298° F. The energy potential under these conditions is slightly over 2,000,000-ft.-lb., the equivalent of 1 lb. of nitroglycerine!

Sludge digestion now proceeds at a rather normal pace after a somewhat stormy starting-up period. Total gas production in September was 4,321,790 cu. ft. for a daily average production of 141,060 cu. ft. Assuming 100 cu. ft. of gas to weigh 6.7 lb., 283,544 lb. of solids were reduced by conversion during the month.

Little Miami digested sludge being withdrawn for final disposal by vacuum filtration and incineration contained 8 per cent total solids, of which 41.0 per cent was volatile matter. Prior to conditioning with ferric chloride, the sludge alkalinity is reduced by elutriation from 3,000 p.p.m. to 650 p.p.m.

December, 1954

The average concentration of suspended solids in the Little Miami raw sewage for the month of November was 307 p.p.m. The effluent contained 152 p.p.m. for an over-all average removal of 50.5 per cent. The raw sewage B.O.D. averaged 160 p.p.m. with an effluent of 97 p.p.m., for a removal of 39.4 per cent.

Cincinnati City Manager, C. A. Harrel, on December 1, informed the City Council that the sewage disposal section of the City Engineer's office would conduct a continuous survey for gases in the Mill Creek interceptor sewer. This is being done because of the explosive gases present in the sewer in the early part of November.

Most big U. S. steel mills report using up to 230 m.g.d. of water. Put

another way, the national average for water consumption per ton of steel produced is about 65,000 gal. Kaiser steel company reports using only about 1,400 gal. of new water and recirculates 50,000 gal. for every ton of steel produced. Over-all its reclaiming system requires only 1,400 gal. of new water per ton of steel. Their Fontana, Calif., steel mill is located in a region where water is a premium item.

Polluted water can be as bad as no water at all. It can be worse. Polluted water may fail to support life. It can destroy life.

A total of 4,685,760 cu. ft. of sludge gas was produced in November. The suspended solids loading indicates an equivalent population of 142,000. On this basis, the gas per capita gas production would be 1.10 cu. ft.

One pound of activated sludge solids is equivalent to ½ gal. of fresh cow's milk with respect to kinds of amino acids present (protein derivatives).

The word "automatic" should be used with great care, since anything that moves is subject to failure of operation at some time.

On November 24, the laboratory men completed B.O.D. test No. 1000.

On the whole, the two requisites that are most important in the operation of a Diesel engine are lubrication and cooling water.

PUMPS FOR AN EXPANDING SEWAGE SYSTEM

Embarked on a major program of expansion and improvement in sewage handling, Topeka, Kans., has found that its varied and extensive pumping equipment, installed over a period of 26 years, can continue to serve with remarkably few additions. Some pumps which have been functioning efficiently since 1928 are marked for important roles in the new system.

The city's principal problem through the years has been a population growth which has continually outstripped both treatment and collecting facilities. As a result, with the population increasing from 33,608 in 1900 to approximately 100,000 today, disposal facilities have lagged far behind the demand, and more and more raw sewage has been discharged directly into the Kansas River. Many districts found it necessary to combine both storm and sanitary sewage lines, further aggravating the situation.

Another complicating factor was the shift in population caused by the flood of 1951, the largest and worst on record. For every home this flood swept away north of the Kansas River, where most of the devastation was centered, a dozen or more were constructed to the south and west, the highest portions of the city. This placed unprecedented strains on existing sewers and forced the construction of new trunk lines into outlying areas.

Meanwhile, the Air Force reactivated and expanded its base at Forbes Field, 4 mi. south of the city limits, giving impetus to the building boom. Between 1950 and 1952 the population jumped from 78,791 to an estimated 92,304, an increase of 13,513 or 12.1 per cent in only two years.

To meet these challenges and also to comply with a recent State Board of Health directive forbidding further pollution of state waters, Topeka has undertaken an extensive modernization and expansion program, calling for the addition of more than 16 mi. of relief sewer and the construction of two new lift stations.

The effect of the new program will be to coordinate the seven individual sanitary systems within a single master plan of interconnecting sewers, channeling all raw sewage into the sewage

treatment plant, which is presently being expanded from 8.5 to 14 m.g.d. This will end all normal discharge of untreated sewage into the Kansas River and connecting waters and will eventually lead to a full separation of storm and roof water from the sanitary systems.

Five underground stations, equipped with a total of 10 vertical close-coupled pumps, have been added to the Topeka system in recent years, facilitating expansion into outlying areas and cutting construction costs to a minimum. Each of these highly-compact, fully-automatic units consists of a steel tank-like pump chamber and entrance tube, a pair of vertical close-coupled pumps, automatic controls, and a ventilation system to keep the station clear of sewage gases at all times and prevent corrosion by dehumidifying the air as it enters.

The stuffing boxes on these pumps are kept supplied with a steady flow of grease under pressure by a special hydraulic-ram mechanism actuated by the pressure in each pump's discharge line. As the pressure builds up, it forces the ram in a connecting tube to push a continuous supply of grease into the stuffing box, keeping the box packed at all times. Pump operation is controlled by automatic air pressure controls actuated by sewage level in the wet well. A roving operator periodically checks the operation of the stations.

Topeka presently has 16 lift stations and a total of 36 pumps ranging in capacity from 375 to 15,000 g.p.m. The latter pump is located in a flood pumping station. In rainy weather when the flood gates remain open the overflow from the collection system is gravity by-passed to the river. However, when the flood gates are closed the overflow is pumped to the river.

The handsome residence, complete with gables and landscaping (Figure 1), is actually a flood station and located in one of Topeka's nicer neighborhoods. This duplex is "home" to pumps rated at 4,500 g.p.m., 7,500 g.p.m., and 15,000 g.p.m. housed in the left half of the building, while a department employee and his family live in the other half.

FIGURE 1.—This attractive Topeka, Kans., duplex residence is "home" for sewage lift pumps, housed on the left, and a sewage department employee's family on the right.

A useful emergency pump included in this expanding system is a 3-in., 200-g.p.m., semi-portable bladeless impeller pump. It is ready for immediate action should expansion problems or flood conditions warrant its use.

The city is hopeful that present efforts to provide adequate collection system capacity and treatment facilities will handle the sewage from this segment of America's growing suburban population.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"Any man is always as young as he feels, but never as important." H. B. H. G.

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Greater Winnipeg (Man.) Sanitary District for the Year 1953 *

By N. S. Bubbis, *General Manager*

Contracts were let early in 1953 for the construction of additional treatment facilities at the main treatment plant. The work included a third primary clarifier and four 85-ft. diameter heated digesters, together with equipment and other appurtenances.

The experimental operation of the sludge lagoons continued throughout 1953. The original work was begun in 1950 and reported in the 1952 Annual Report (see This Journal, **25**, 11, 1361; Nov., 1953). From the information obtained, the consulting engineers recommended that the basic method of sludge dewatering should be by the use of lagoons, but that new vacuum filters and additional elutriation facilities be installed to provide flexibility of operation. Two digesters were dewatered during the summer.

Control of industrial wastes from packing and slaughter houses was continued. Practically no paunch manure or pig toe-nails were in evidence, resulting in no breakdown in the pumping stations or resulting overflow of raw sewage. This has eliminated a major source of pollution.

The sanitary district serves 323,704 inhabitants in Winnipeg and surrounding municipalities. A large increase in sewer extensions took place in the surrounding areas. All water service connections in Winnipeg except 735 are served by sanitary sewers. Three neighboring municipalities not now in the district were required by legislature to arrange to enter the district by January 1, 1955.

Maintenance of 16 pumping and comminutor stations for sanitary sewage and 21 flood pumping stations continued without difficulty.

A summary of 1953 operating data is given in Table I.

* For last previous extract see This Journal, **25**, 11, 1358 (Nov., 1953).

TABLE I.—Summary of 1953 Operating Data, Greater Winnipeg Sanitary District *

Item	Average
Equivalent population, est.	405,700
Precipitation (in.)	28.28
Sewage flow (m.g.d.)	31.6
Grit (cu. ft./m.g.)	1.2
Settleable solids:	
Plant influent (ml./l.) †	5.9
Clarifier effluent (ml./l.)	1.8
Removal (%)	69.9
Suspended solids:	
Plant influent (p.p.m.) †	299
Clarifier effluent (p.p.m.)	129
Removal (%)	56.5
B.O.D., 5-day:	
Plant influent (p.p.m.) †	265
Clarifier effluent (p.p.m.)	135
Removal (%)	49.5
Raw sludge to digesters, total (m.g.)	12.9
Dry solids (tons/day)	12.1
Solids (%)	9.8
Volatile (%)	67.1
Sludge from digesters to filters, total (m.g.)	5.76
Sludge from digesters to lagoons and sandbeds, total (m.g.)	0.8
Digested sludge:	
Solids (%)	6.2
Volatile (%)	48.7
pH	7.3
Sludge gas:	
Produced, total (mil. cu. ft.)	63.35
Used for heating, total (mil. cu. ft.)	18.76
Wasted, total (mil. cu. ft.)	44.59
Produced, daily (cu. ft.)	173,808
Wasted, daily (cu. ft.)	107,467
CH_4 (%)	67.6
Elutriated sludge:	
Sludge handled, total (m.g.)	5.76
Dry solids, effluent (%)	.51
Alkalinity (p.p.m.)	1,271
pH	7.1
Solids (%)	9.8
Volatile (%)	47.3
Sludge cake from plant:	
Total, wet (tons)	1,650
Total, dry (tons)	436.9
Ferric chlorine used:	
Total (lb.)	44,377
Dose (% of solids filt.)	4.9
Days filters operated	57
Filter rate (lb. sol./sq. ft./hr.)	4.0
Cost of operation ($):	
Collection	73,646.43
Treatment	190,928.92
Total	264,575.35

* All flows and capacities in U. S. gallons.

† Includes solids in elutriate and filtrate returns.

Annual Report of the Cranston, R. I., Sewage Treatment Plant for Year Ended September 30, 1953 *

By Walter C. Anderson, *Superintendent*

In its 12th year of operation the plant treated 1,140 m.g. of sewage. This was an increase of 82 m.g. over the flow of the preceding year and was the largest amount treated since the plant was placed in operation. The sewage consisted of approximately 75 per cent domestic and 25 per cent industrial wastes, including an industrial waste volume increase of 10 per cent over 1952. Utilizing activated sludge and post-chlorination, the overall plant efficiency was 92 per cent removal of the suspended solids and 93 per cent for the oxygen requirements measured as B.O.D.

Effluent was discharged into the Pawtuxet River, a stream having a 200-m.g.d. average flow but with a critical, dry-weather flow of only about 26 m.g.d. Designated as a Class C stream by the Rhode Island State Health Authorities, the Pawtuxet River should contain a minimum D.O. of 5 p.p.m. and a maximum B.O.D. of not more than 5 p.p.m. Consequently year-round chlorination of the final effluent, as required by the state health authorities consumed 28,640 lb. of chlorine. This was 7,768 lb. more than the preceding year and was due to the high chlorine demand of the additional industrial wastes treated. Average rate was 3.0 p.p.m. with an average detention time of 10 min., resulting in an average chlorine residual of 0.56 p.p.m. The resulting condition of the river justified the efforts expended on treatment. Average D.O. below the treatment plant was 7.5 p.p.m. and the B.O.D. was 4.60 p.p.m.

* For last previous extract see This Journal, **25**, 12, 1467 (Dec., 1953).

The amount of oil required for emergency heating needs was reduced from 2,830 gal. for the 1951–52 year to 650 gal. during 1952–53. This is due to the installation of new control equipment, resulting in more stable and dependable operation of the boiler through better adjustments to utilize more of the digester gas. Even with practically 100 per cent utilization of the digester gas for heating purposes, approximately 47 per cent of the 16,100,000 cu. ft. of gas produced was burned in the waste gas burner.

The total net cost for operating the treatment plant during the fiscal year amounted to $64,038.75. This is equal to $56.17 per m.g. treated and is a reduction of $3.71 per m.g. below the cost for the previous year. Approximately 57 per cent of the city's population is now connected into the sewer system, an increase of 6 per cent during the year.

Cesspool Wastes

The city's domestic cesspool wastes have been easily handled at the treatment plant. These wastes were discharged at the inlet to the grit removal unit for the removal of grit, and the remaining liquid wastes then passed through the plant processes. The Cranston cesspool wastes averaged 50 loads per month, for which a charge of $1.60 per load is made.

During the past year an agreement was made with the health authorities of the neighboring city of Warwick to dispose of their cesspool wastes. This required a change in the Cranston city ordinances to permit the bringing in of these out-of-city wastes. The Warwick cesspool wastes averaged 100 loads per month and the same charge per load was made as for Cranston wastes. The total cesspool wastes received during the year amounted to 1.8 m.g. or 0.2 per cent of the total sewage flow.

Textile Wastes

Plant-scale experiments to absorb a portion of the highly alkaline wastes from a large textile industry, the Cranston Print Works, were begun during the year and continued. The Rhode Island State Department of Health had requested the textile company to abate pollution of the small Pocasset River. Accordingly, a portion of their worst wastes, including dye house wastes, kier liquors, print shop wastes, color shop wastes, and toilet wastes, were diverted from the river and discharged into the city's sewers. The company agreed to discharge their wastes at a fixed, continuous rate and adjustments to the treatment plant processes were then tried. Discharge of the partially neutralized textile wastes began at 100,000 g.p.d. and was increased to 700,000 g.p.d.

Even with this volume of wastes being diverted, the condition of the Pocasset River did not improve to the satisfaction of the state health authorities. Plans are under way to discharge an additional 600,000 g.p.d. of soap house wastes to the sewers.

Apparently the treatment plant can handle up to 700,000 g.p.d. fairly well. However, as additional loadings increase, equipment capacities may be the deciding factor in determining the adequacies of the treatment plant processes. Addition of the textile wastes required an increase in air supply from 2,500 to 6,500 cu. ft. per min. in order to maintain a D.O. of 2.0 p.p.m. in the mixed liquor. Also, the chlorine required to maintain a residual in the effluent necessitated increasing the chlorinating equipment capacity from 200 to 400 lb. per day.

Grit Removal

The small manually cleaned bar screen installed during the preceding year effectively prevented rags from clogging the impeller of the organic return pump and has eliminated that source of previous trouble. Screenings are disposed of by burial or comminuting.

Two breaks in the gravity sewers, plus the discharge of additional cess-

pool cleanings, caused an increase of 931 cu. ft. in the amount of grit removed. Analysis showed a volatile solids content of 1 per cent.

Primary Settling

The scum removal equipment handled 43,590 gal. of scum. Recirculation of the bottom liquor in the scum well was continued with satisfactory results. Total flow through the primary settling tanks includes the sewage flow, waste activated sludge, wash-water overflows, recirculated chlorinated effluent, plus supernatant digester liquor.

Aeration Tanks

Chlorination of the returned sludge was practiced from January through May, resulting in a lowering of the sludge index from 146 to 83. Subsequently, the admission of increasing amounts of textile wastes resulted in a steadily increasing sludge index. Suspended solids of the mixed liquor averaged higher than the year before, being 2,656 p.p.m. with an index of 149.

Final Settling

Both final settling tanks were used throughout the year, giving an average detention of 2.63 hr. and discharging a final effluent averaging 5.8 p.p.m. D.O. Operation continued along the same lines as the preceding year.

Digestion and Filtration

Normal single-stage digester operation was experienced; on only one oc-

TABLE II.—Summary of Operating Data for the Cranston, R. I., Sewage Treatment Plant for the Fiscal Year 1952–53

Item	Average
Trib. pop., est.	32,958
Sewage treated, total (m.g.)	1,140.24
Sewage flow (m.g.d.)	3.12
Per capita (g.p.d.)	95
Indus. wastes (%)	25
Grit (cu. ft./m.g.)	1.46
Grease (gal./m.g.)	124
Primary settling data:	
Det. period (hr.)	1.94
Sludge (gal./m.g.)	5,774
Skimmings (gal./m.g.)	38
Aeration tank data:	
Aer. period (hr.)	4.99
Air supplied (cu. ft./ gal.)	1.07
Ret. sludge (%)	37
Mix. liq. susp. sol. (p.p.m.)	2,656
Sludge index	149
D.O., outlet (p.p.m.)	4.9
Final settling data:	
Det. period (hr.)	2.63
Sl. returned, tot. (m.g.)	485
Sl. wasted, tot. (m.g.)	14.13
Sludge susp. sol. (p.p.m.)	5,089
D.O., effl. (p.p.m.)	5.8
D.O., sludge (p.p.m.)	1.9
Chlorination data:	
Total used (lb.)	28,640
Applied (p.p.m.)	3.0
Residual (p.p.m.)	.56
Sludge digestion data:	
Sl. to dig., total (m.g.)	6.57
Solids (%)	5.10
Gas produced:	
Total (mil. cu. ft.)	16.11
Per m.g. sewage (cu. ft.)	14,132
Per capita daily (cu. ft.)	1.33
Vacuum filtration data:	
Dig. sl. to filt., tot. (gal.)	747,362
Solids (%)	3.71
Vol. solids (%)	51.7
Filter cake, total (tons)	520
Cake moisture (%)	78.3
Cake dry solids, tot. (tons)	122.5
$FeCl_3$ used, tot. (lb.)	13,790
Ratio, $FeCl_3$ dry solids (%)	5.61
Filter rate (lb./sq. ft./hr.)	3.23
Suspended solids:	
Raw sewage (p.p.m.)	176
Final effl. (p.p.m.)	15
Reduction (%)	92
5-Day B.O.D.:	
Raw sewage (p.p.m.)	233
Final effl. (p.p.m.)	16
Reduction (%)	93
Operating cost ($):	
Salaries	34,157.88
Electricity	13,229.61
Chemicals	4,874.99
Supplies	1,898.74
Telephone	267.99
Supplies and repairs	3,809.06
Equipment	3,275.50
Water	1,856.78
Miscellaneous	2,490.60
Total, gross	65,861.15
Credit, cesspool fees	1,822.40
Total, net	64,038.75
Per m.g. treated	56.17

casion was it necessary to add lime for pH control. Several methods were tried to improve the quality of the supernatant liquor. The latest consisted of elutriating the supernatant liquor to de-gas and concentrate the solids, which were then pumped to the second digester. The supernatant liquor from the second digester contained less than 0.5 per cent solids and caused no problem in the primary tanks. Storage of the sludge in the second digester helped to thicken it.

Over-all results of digester and filter operation were much improved. The rate of filter production of the elutriated sludge was 32 per cent higher than the previous year, averaging 3.23 lb. of solids per square foot per hour. Ferric chloride requirements were reduced 24 per cent on a dry solids basis.

Maintenance

Some years ago, a detailed schedule was prepared in cooperation with a major oil company for periodic and proper lubrication of all plant equipment. This included not only the type of lubricant, but also the amount per service period. Strict adherence to this schedule has resulted in excellent operation of the mechanized units. Much of the equipment has been in continuous service in excess of 105,000 hr. without break-downs or major overhauls. Conscientious servicing by the operators has been a major factor.

Installation of additional piping to utilize the effluent for some plant water needs has resulted in economy of operation.

Table II summarizes operating data for the year.

Third Annual Report of the Boise, Idaho, Sewage Treatment Plant, December 31, 1953

By Andrew J. Wahl, *Superintendent*

General

The Boise, Idaho, activated sludge plant was placed in operation in late 1951. Today it serves 7,900 connections and receives an average daily sewage flow varying from 5.2 to 12 m.g.d. Flow variation is caused by ground-water infiltration during the irrigation season. The chlorinated effluent is discharged to the Boise River, which has a variation in flow from 50 to 7,500 c.f.s.

Improvements during the year covered a variety of projects, ranging from grading and landscaping to the construction of additional garage space and a greenhouse (see This Journal, **25**, 6, 795; June, 1953). Equipment was rented from construction of additional sludge drying area.

The cast-iron impeller of the raw sewage pump had worn ¼ in., and was removed and rubber coated. Efficiency increased and periodic observations will be made to determine the effective life of the coating.

Sewer Maintenance

During 1953 there was a 30 per cent decrease in the number of calls resulting from sewer stoppages. This improvement is credited to a planned program of sewer line rodding and inspection. In addition a short-wave radio equipped service truck is available for immediate service.

Each week the mechanical sewer cleaning equipment is lubricated, inspected and washed. Not more than 8 hr. were lost due to mechanical repair of equipment. Two men, instead of four, now handle the sewer cleaning and provide 24-hr. service in case of emergencies.

Approximately $17,000 is budgeted and contracted for each year to replace sewer lines having the greatest amount of infiltration.

TABLE III.—Summary of 1953 Operating Data at the Boise, Idaho, Sewage Treatment Plant

Item	Average
Population equivalent, est.	35,710
Sewage flow (m.g.d.)	6.9
Suspended solids:	
Plant influent (p.p.m.)	148
Clarifier effluent (p.p.m.)	64
Final effluent (p.p.m.)	8
Removal (%)	94
B.O.D., 5-day:	
Plant influent (p.p.m.)	93
Clarifier effluent (p.p.m.)	71
Final effluent (p.p.m.)	7
Reduction (%)	93
Aeration tank data:	
Aer. period (hr.)	6.1
Air supplied (cu. ft./gal.)	.73
Returned sludge (%)	34.3
Mix. liq. susp. sol. (p.p.m.)	1,070
Sludge index	325
D.O. (p.p.m.)	2.6
Sludge susp. sol. (p.p.m.)	3,795
D.O., final effluent (p.p.m.)	5.6
Chlorination data:	
Total used (lb.)	19,700
Applied (p.p.m.)	1.0
Sludge digestion, data:	
Sludge to dig. (gal./day)	53,243
Temp. (° F.)	92.5
pH	6.9
Sludge gas data:	
Produced, total (mil. cu. ft.)	20.14
Used, est. (cu. ft./day)	37,000
Operating cost ($):	
Treatment, operation	53,511.79
Improvements and equipment	3,664.66
Collection system	12,984.43
Sewer improvements	15,373.00
Total	$85,523.88

Sewer Service Charge

A recent increase in the water rates by the private water utility serving Boise required a change in the sewer service charge. Previous to this change charges were based on one-half the average water billing for Dec., Jan., and Feb. The revised service charges are based on a percentage of the low month water consumption, with a minimum rate of $0.60 per month. All accounts are billed by the City on a quarterly basis, with delinquent accounts becoming tax leins upon the property. Collections to date have been very satisfactory.

The 1953 operating data are summarized in Table III.

PUBLIC RELATIONS FOR MUNICIPAL PERSONNEL*

By Walter L. Dunn

Assistant Professor, University of Washington, Seattle, Wash.

What is public relations? Any public utility, whether it be water, sewage, light, or gas, has some type of public relations. Such public relations may be classified as good, bad, or indifferent.

Indifference of the public, or lack of information about the utility, may be as detrimental as bad public relations. Little support or understanding can be expected from people who either do not know about the utility or who are just plain "agin' it."

What then is good public relations? One of the best and simplest definitions of good public relations is that it is (a) doing good, and (b) getting credit for it.

It should be noted that there are two requirements. Each is equally important.

To maintain good public relations, good service must be furnished. Without good service, poor public relations is an almost inevitable result. However, unless people are informed of

* Presented at 1954 School for Water Works, Sewage Works, and Industrial Waste Operators and Managers; Montana State College; Nov. 17–19, 1954.

what is being done and planned they may take the services for granted.

If the water department, sewage treatment plant, city manager, or city engineer does not get credit for a job well done, they probably will not be able to continue doing a good job! Why? Because the support of the public is necessary to get the regular monthly budget. Even more so, the complete understanding and support of the people is needed to obtain improvements and replacements.

Another need for good public relations is to satisfy a basic need of the people involved—that of receiving respect from others for doing a job well. This need is universal in all, whether it be the mayor, the city manager, an operator, a service man, or a ditch digger. By doing a good job, and getting credit for it, they can be more certain of their jobs, and are much more likely to get regular raises and larger budgets.

Successful superintendents must give talks at PTA meetings, to civic groups, and before school groups. Newspapers must be kept informed. The public should be informed when repairs are made or the streets torn up.

As a check on his public relations effectiveness, each superintendent should honestly appraise the question: "If a survey was made in my town, would most people know: (a) where their sewage goes? (b) is it treated? (c) what does it cost?"

Public relations can not be left to one person in the utility; it is the concern of every employee—field man, office man, clerk, or superintendent. One rotten apple in the barrel will spoil the good ones and a single impolite or thoughtless act by one person brings discredit to the rest. Everything done by municipal personnel in the normal conduct of business produces some reaction, whether it be good, bad, or indifferent. The summation of all these actions determines the public relations.

Each little thing that is done might be compared to driving a spike in the plank of good public relations. It takes a lot of little "pings" with the hammer to add up to the final "pong" which drives the spike home. Some of the things which can be done are:

1. Encourage visitors to come to the plant, particularly school groups. Be sure all city officials have visited the plant. Set up a regular tour and prepare a talk any employee can follow as he guides visitors through the plant.

2. Make a set of colored slides of the plant, and use them as a basis for talks. It costs about $3.50 to make a set of 20 colored slides that will help tell a story better than words alone. Also, the U. S. Public Health Service has many slides showing cutaway views of water and sewage treatment units such as trickling filters and digesters. These can be obtained and worked in with your local slides.

3. Prepare a flow diagram of the plant showing pertinent data. Give a copy to each visitor—and have a large copy mounted on the wall.

4. At the sewage treatment plant:

   (a) Provide adequate parking area.
   (b) Keep the plant appearance neat and clean; maintain lawns, shrubbery, and fences.
   (c) Use signs; show directions to the plant, the name of the plant, locate the rest rooms, label the treatment units and equipment, and use different colored paints on pipes for ease in following the flow.
   (d) Have a definite place for all tools, and keep them in place.
   (e) Prepare exhibits, to be used at the plant, at fairs, and in store windows.

5. Establish a definite public relations program. All employees must know what constitutes good public relations and regular meetings should be held, with 30 to 50 min. devoted to public relations. Guided group dis-

cussions are effective for this type of meeting.

Good public relations is a job for everyone, and goes on at all times. Big business recognizes the importance of good public relations and spends a lot of money on it. One of the largest companies in the country puts out a card for its employees that says, in effect: Let us not forget that anyone who will visit us, or call on the telephone, or seek our aid, offers to us the privilege of creating goodwill. Let us not throw away that privilege.

IN-PLACE REPAIR OF CORRODED PIPE

Approximately 40 ft. of eroded water header was recently repaired using a polyester resin produced by the Celanese Corp. of America. The pipe, which normally flows half full, had large holes in some areas (Figure 1) and the balance was rusted almost paper thin.

The repair procedure used was as simple as it was effective. First, scale was knocked off and two plies of glass cloth, saturated with a self-curing blend of Celanese resin, was applied over the large holes. Leaks were then plugged and two additional plies of glass cloth, thoroughly saturated with the resin, were wrapped about the entire rusted area of the pipe.

Thirty gal. of resin were required and total cost of materials amounted to only $138. The big advantage was that the pipe could be repaired in place, thus avoiding disconnections and the costly man-hours that would have been involved if the section was replaced.

The reinforced polyester laminate has ample strength to carry the weight of a man (Figure 2). It is claimed that the laminate will not rust, rot or absorb moisture, that long trouble-free service can be expected, and that accidental ruptures can be easily repaired.

FIGURE 1.—Unmaintained header has very thin sections and a badly corroded top.

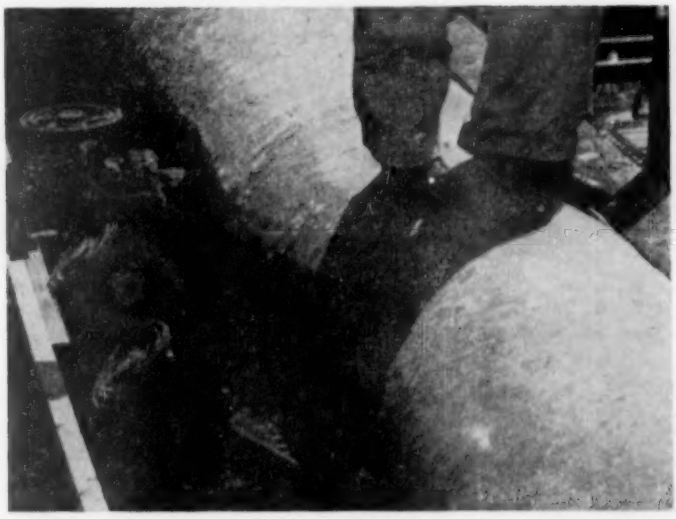

FIGURE 2.—The corroded section shown in Figure 1 can now support the weight of a man.

TIPS AND QUIPS

Sewage Effluents for Unrestricted Re-Use

Study into the further biological purification of sewage effluents for unrestricted re-use was reported by G. J. Stander, Chairman of the South African Branch, Institute of Sewage Purification, as a vital problem of the near future in his country. Commenting at the 1954 Conference of the Institute, Dr. Stander stated that intensive investigational work was in progress. The principle objective of the studies is to evolve a method of biological purification that will produce an effluent indistinguishable from natural water. This sewage effluent should have all organic matter dissipated, the ammonia nitrogen absorbed or oxidized, and much of the nitrates removed or adsorbed. In addition it must conform to specific standards for bacteriological quality.

Laboratory Siphon and Hand Pump

Simplicity itself, a rubber bulb and tubing have been incorporated into a handy laboratory siphon and hand pump suited for those tedious and often difficult laboratory tasks requiring the transfer of solutions, or the draining of containers. Pump action starts the siphon and easily pumps or siphons liquids without spilling or splashing.

Made of synthetic rubber and using plastic check valves, the siphon avoids the use of metal. It is unaffected by most inorganic solutions, mineral and animal oils, and low concentrations of organic solvents.

Costing $3.00, the unit is available from General Scientific Equipment Co., 2700 W. Huntingdon St., Philadelphia 32, Pa.

Plumber's Tools For Einstein

Dr. Albert Einstein's recent assertion that if he had to do it over again he would be a plumber, has led one manufacture of plumber's tools to put out the welcome mat for Dr. Einstein if he should care to try his hand at the plumbers' honorable profession.

As a token of friendly greeting, officials of the Toledo Pipe Threading Machine Co., Toledo, Ohio, sent a kit of four pipe tools to the great scientist. Included were a hand threader for pipe, a pipe cutter, a pipe wrench, and a vise.

Accompanying the gift was a card which bore the greeting: "To a great scientist, scholar and teacher—so that you may become a great plumber we present you with these pipe tools."

When Dr. Einstein has mastered the tools, maybe we can persuade him to unravel the maze of piping we bump our heads on in the digester control house. At least if he could translate it into his "expanding universe" we'd have a little room to move around in!

Permanent Starch Indicator Solution

Like techniques in hand-made glass blowing and wine making that are passed from generation to generation, the following laboratory tip has been passed along until its appearance in the *Quarterly Newsletter* of the California Sewage and Industrial Wastes Association.

A permanent starch indicator solution can be prepared as follows:

Make a paste using 2 g. of soluble starch and small amounts of cold water. To the paste add 350 ml. of cold distilled water and stir to produce a suspension. While stirring, add 7 g. of reagent grade potassium hydroxide and continue stirring until the hydroxide is dissolved. Allow the solution to stand for about 1 hr. to insure complete action by the alkali. With reagent grade concentrated hydrochloric acid make the mixture neutral or slightly acid to litmus; approximately 10 ml. of acid is sufficient. Finally, add 1 ml. of glacial acetic acid as a preservative.

The result is a stable starch indicator solution for D.O. determinations. According to Terry Masuda, Public Health Chemist, State of California, considerable success has been had using this solution with or without refrigeration. Adverse conditions, and temperature variations, both in the laboratory and in the field, have not resulted in deterioration or loss of sensitivity of the starch-iodine blue complex formation.

First Aid Training

We noted recently that a sewage treatment plant superintendent conducted a first aid school for the men on his staff. A trained Red Cross instructor taught the course for a 20-hr. schedule. Results: Eleven of the staff earned first aid certificates.

This course not only provided the plant with trained men in case of an accident and thereby assures protection for fellow workers, but it also makes each operator a valuable asset to his community and develops respect by the public for the sewage treatment plant personnel.

Give-Aways

Visitors to one sewage treatment plant are presented with a neatly packaged bag of dried and shredded digested sludge. Enclosed with the package is a leaflet describing the processing of the sludge and suggesting its use for potted plants and other home gardening activities.

Perhaps this is a move to cash in on the sales-building give-away programs of the packaged cereal industry. But what will the poor plant operator do with all the accumulated box tops?

Technological Odor Elimination

Elimination of offensive odors and pollution of streams resulting from fish and animal processing may be at hand if a new process for dehydrating and defatting tissues at low temperatures is widely adopted. This was announced by Messrs. Levin and Finn of the University of Illinois at the recent annual meeting of the American Institute of Chemical Engineers in New York City.

Developed to produce stable fish meal and fish oil for human food and animal use, the process provides a means of in-plant control of waste products.

Technological developments of this type provide the most economical and satisfactory answer to waste disposal problems. If the waste cannot be economically treated, perhaps it can be eliminated, or salvaged. Each day brings a new development in this fascinating problem of resource protection and utilization.

Oil Fire Damages Sewage Treatment Plant

Malicious dumping of gasoline and oil into the sanitary sewer system was blamed for a 2-hr. fire that swept through the Aberdeen, S. Dak., sewage treatment plant. Fire broke out about 10:20 AM in one corner of a settling basin and quickly spread to other basins. The basins, located outside, are adjacent to the brick building housing the motors, recorders, flumes and sludge heater.

Superintendent Siger Bies failed to stop the spreading of the fire with a hand extinguisher, due to the heat. Fire equipment and fire fighters were hindered in their fight because a fire hydrant was not available. Water was finally obtained from a nearby creek and the flames kept confined to the basins. Spectators reported flames leaping as high as 200 ft. and giving every appearance of destroying the plant.

Fortunately, damage was light, resulting in damaged wiring, a burned out motor, and some weakened brick walls.

Origin of the fire is believed to have been caused by a spark from the plant heating system igniting oil in the basins. An oil film had been noticed on the incoming sewage during the week previous to the fire. It had been skimmed off several times and all attempts to trace its source had failed.

Moral—Have a good strong sewer ordinance to keep out oil and keep it enforced; then when fire breaks out have fire hydrants available and an adequate source of water.

Thawing Grit

Freezing of grit on the ramp in mechanical grit removal equipment can be reduced to a minimum by installing a small gas burner under the ramp. This is a good use for waste gas and a report from Michigan claims freezing of the grit was prevented except during below-zero weather.

Fibre-Glass Cabinet

What would appear to be a sure deterrent to corrosion of chlorinator equipment cabinets is the introduction by Fisher and Porter Company of a corrosion-proof, polymer-impregnated, fibre-glass cabinet to house high-capacity solution feed chlorinators. The unit is reported to require no paint maintenance. However, caution is still very much the word in handling chlorine.

World Health Day

With a theme of "Clean Water—Basis of Health," April 7 is to be recognized as World Health Day. Clean water, of course, is the objective of all the efforts of the Federation and its members.

Editorial

SECRETARY WISELY LEAVES FEDERATION STAFF

When the Federation decided to engage an Executive Secretary in 1940, it was fortunate indeed to find available the services of William H. Wisely.

"Pete," as he is known to his multitude of friends, had undertaken graduate study in Sanitary Engineering at the University of Illinois, his alma mater, while he served the Urbana-Champaign Sanitary District as Engineer-Manager. This was as a follow-up on his undergraduate work at the University, where he had been one of the most outstanding proteges of that excellent sanitary engineering teacher, Professor Harold E. Babbitt. His acceptance of part-time employment with the Federation required giving up his immediate educational plans and the establishment of the first fixed office of the Federation at Urbana in 1941. Later, in 1943, the office was moved to its present location in the neighboring city of Champaign.

His careful tending of the infant Federation through those early years has been a prime factor in the persistent growth of the organization. During his period of service the number of Member Associations has grown from 26 to 38 and the total individual membership of the Member Associations has jumped from 2,819 to 6,278. Furthermore, the geographic spread of Member Associations includes two in the British Empire, three in Europe, and one in Puerto Rico, in addition to Canada and those in the United States. From U. S. associations serving 34 states, the areal coverage has risen to 46 states.

At the same time, the scope of Federation interest and influence has broadened. An achievement of note was the inclusion of industrial wastes as a primary Federation interest in 1950. Thus the persons dealing with industrial waste pollution had a common meeting ground with those primarily concerned with domestic sewage disposal. This union was helped by stream sanitation principles which naturally affect all waterborne waste discharges. At the same time, the Federation's bimonthly *Sewage Works Journal* became a monthly publication under the name *Sewage and Industrial Wastes*.

Perhaps "Pete's" greatest contribution to the field has been in the role of Editor of Federation publications. While this has consisted of the prime editorial responsibility of the Federation's monthly, *Sewage and Industrial Wastes*, it has also included the editorship of such special publications as the "Twenty-Year Index" and the organization's five Manuals of Practice.

To assist Mr. Wisely in the office activities necessary to such an operation there was a single stenographer at the outset. Then in 1943 he became the Federation's first full-time Executive Secretary and Editor, and by 1954 the staff helping him had grown to six. Throughout the years he planned the detailed operation of the office and selected all employees. Anyone dealing with the office in person, by telephone, or by mail immediately senses a spirit of willingness to serve and a feeling of deep loyalty to the Federation on the part of every employee. Upon analysis, one cannot escape the fact that this is some of Pete Wisely's spirit showing through just as surely as a child reflects his parents' guidance and example.

Along with these activities he has been the central figure in Federation convention planning, committee organization, and contact with Member Associations. By correspondence and visitations to Member Association meetings as one of four officers who make these contacts, Mr. Wisely has given generously of his time and counsel to secretaries and other officers of local associations. Besides making numerous contributions to the technical sessions of these meetings and to the literature, he gave inquiries to the headquarters office much personal attention and rightfully took great pride in this service of the organization.

Mr. Wisely's topnotch stewardship of the Federation, along with his outstanding professional and personal qualifications, made him a natural selection for the position of Executive Secretary of the American Society of Civil Engineers. He will assume his new post in May, 1955, after serving the organization as Associate Secretary beginning in January. The Federation has lost the best "boss" it could have. We extend to him our congratulations and best wishes for a long and rewarding career with ASCE!

R. E. F.

Reviews and Abstracts*

Rate of Gasification of Municipal Night Soil. By I. Horasawa. *Bull. Inst. Pub. Health* (Japan), 3 (June, 1953).

Fresh night soil does not yield gas, but municipal night soil gasifies to some extent, probably due to soil contact and storage in privies. Digestion is favored by addition of carbohydrates and by seeding. The extent of gasification occurring in the privies depends on the length of time before collection and on the privy temperature. In most Japanese towns the municipal agencies collect the night soil at intervals of from two weeks to 20 days.

H. P. O.

Report on Filtration Experiments at Dewsbury. By R. S. Oldroyd. *Jour. Inst. Sew. Purif.* (Brit.), 122 (1951).

Experimental work on alternating double filtration, carried out on laboratory-scale filters with a single filter as control and then on pilot-scale filters outdoors, was compared with similar work on high-rate filtration using recirculation. This was followed by full-scale experimentation with alternating filtration.

The sewage treated contained about 40 per cent textile wastes derived from piece scouring and dyeing. Generally speaking, alternating double filtration with daily alternations gave slightly better results than recirculation. Both methods are practicable at a treatment rate of 200 g.p.d. per cubic yard, equivalent to the daily dry-weather flow.

Recirculation had advantages in more economical use of pumping energy and greater simplicity of works operation with a constant flow through the filters and humus tanks.

H. P. O.

The Availability of Nitrates in Sewage Effluents. By C. Jepson. *Jour. Inst. Sew. Purif.* (Brit.), 148 (1951).

Although oxidized nitrogen is a potential source of oxygen, the latter does not become available for biological life until all the free dissolved oxygen has disappeared. Presence of nitrate in an effluent can delay or prevent the onset of putrescence. Given an adequate retention period during which any dissolved oxygen present is exhausted, settled sewage may be improved in quality by the reduction of oxidized nitrogen present in a filter effluent used as a diluent. To obtain a correct estimate of oxidized nitrogen, analysis should be made as soon as possible after sampling or special precautions taken to retard biological action.

H. P. O.

Further Mechanical Developments in Rectangular Tank De-Sludging. By H. D. Thatcher and R. W. Lucas. *Jour. Inst. Sew. Purif.* (Brit.), 171 (1951).

This is a review of developments in mechanized sludge removal from settling tanks, particularly of rectangular plan. The first type discussed is the transfer scraper type for use on several tanks. Modifications include vertically-operated sweep arrangements, end seals, retractable undercarriages, and elimination of the transfer carriage. Also, elimination of the intricate interlocking devices and the heavy bridge and control house. Sludge concentrators, consisting of sweeps to concentrate the sludge trapped in a small end area by the longitudinal sweep, are described. Also discussed is the provision in the floor of sludge collecting troughs instead of hoppers. General results of time-saving studies show the advantages of modern individual tank mechanisms as regards operational costs.

Also included in the studies was a series of tests of different aluminum alloys exposed to corrosive treatment plant conditions. Test locations are in raw sewage, in settled sewage, and in final tank effluent, as well as on the surface of trickling filters. The sewage contains some industrial waste. In general, the aluminum

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns. 325 Illinois Bldg., Champaign, Ill.

after two years exposure shows no marked corrosion. The authors point out, however, that alkaline wastes may present some problems and suggest that in such cases mild steel be used for the underwater structure and light alloys for the superstructure. H. P. O.

The Influence of Trade Wastes from a Gelatine Factory on the Krugersdorp Purification Works. By P. J. J. Pienaar. *Jour. Inst. Sew. Purif.* (Brit.), 187 (1951).

Highly alkaline wastes (pH 11.7 to 12.1) from a gelatine factory, constituting 20 per cent of the total daily sewage (2 m.g.d.) flow, caused serious deposition of $CaCO_3$ at the junction of the industrial sewage collector and the main municipal interceptor. Also, the gelatine wastes caused a noticeable deterioration of the digested sludge, resulting in an increase in sludge drying time from 3 days to 3 or 4 weeks. The digested sludge is very fine in texture and almost colloidal in appearance.

Separation of the factory effluent revealed its effect, the objectionable factors stemming from the high pH and the high protein content. Filter ponding took place in 5 months when the segregated wastes were added to the filter dosing tanks instead of ahead of primary sedimentation.

Pretreatment of the wastes is under study. Most promising of the pilot studies so far undertaken involves treatment of the factory effluent with the combustion products of sludge gas. H. P. O.

Some Observations on the Control of the Breeding of Psychoda Flies in Bacteria Beds. By W. R. Alison. *Jour. Inst. Sew. Purif.* (Brit.), 189 (1951).

Recirculation to obtain high dosage rates is advocated as a suppressive measure, plus seasonal intensive treatment using emulsions of benzene hexachloride. New observational methods had to be devised to suit existing labor conditions.

The observation method adopted consists of galvanized iron plates on which are mounted paper treated with a fly-adhesive preparation. The plates are placed in selected positions on a brick ledge half-way up the vertical filter wall. Rain protection is provided and the plates are positioned so as to be almost vertical.

Results so far show that:

1. The number of emergent flies is a direct function of the atmospheric temperature.

2. Increase of air temperatures and of fly breeding can be expected during November (South Africa), when regular insecticide applications are very necessary.

3. Benzene hexachloride in white fluid emulsion form gives a more lasting control (up to 14 days) than do heavy doses of chloride of lime (3 to 4 days).

4. In one instance, a sudden increase in fly counts was caused not by temperature rise but by sewage septicity, which caused bad settlement and heavy solids loading of the beds. H. P. O.

Water Quality Criteria—Addendum No. 1. State Water Pollution Control Board, Sacramento, Calif. Price, $1.50. (1954).

This addendum brings up-to-date the original report published in 1952 (abs. This Journal, **24**, 11, 1437; Nov., 1952). Embodying 164 pages and containing 371 new literature references from the years 1952 and 1953, the addendum is designed and printed to fit into the organization of the original report. H. P. O.

Biologie und Chemie des ungestanten und gestanten Stromes (Biology and Chemistry of Unregulated and Regulated Streams). R. Oldenbourg, Munich, Germany. 315 pp. Price, DM48 (1954).

This second volume of the "Munich Contributions on Sewage, Fishery and Stream Biology" comprises a symposium of papers relating the findings of investigations on the Rhine-Main-Danube Waterway. The various concepts worked out by the several authors are applied in practical manner to the studies, using the Main and Danube Rivers, and the connecting canal, as examples. H. P. O.

Toxic Fresh-Water Algae. By W. M. Ingram and G. W. Prescott. *Amer. Midland Nat.*, **52**, 1, 75 (July, 1954).

This is a literature review on the toxicity of algae to humans, domestic animals, mammals, birds, and fish. Also included is a review of the literature on the chemistry of toxic algae. A comprehensive bibliography makes the article of exceptional interest to the research worker.

H. P. O.

Federation of Sewage and Industrial Wastes Associations

Annual Year Book
and
Supplemental Directory
1955

OFFICERS

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FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 Illinois Building, Champaign, Ill.

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HONORS AND AWARDS

Honorary Members

The qualifications for Honorary membership in the Federation are set forth in Article II, Section 4 of the By-laws. Honorary Members are elected upon recommendation by a committee comprising the President and four latest Past Presidents, the senior Past President as chairman, in accordance with a policy adopted by the Board of Control on October 23, 1943. Honorary Members elected to date are as follows:

Charles Alvin Emerson.....1941
*Arthur S. Bedell.....1942
Julius W. Bugbee.....1942
Langdon Pearse.....1942
Charles Gilman Hyde.....1943
Howard Eugene Moses.....1943
Floyd William Mohlman.....1944
Willem Rudolfs.....1945
William John Orchard.....1946
F. Wellington Gilcreas.....1948
Wilford Willis DeBerard.....1950
Karl Imhoff.....1953
Harold Warner Streeter.....1953
Albert Edward Berry.....1954
William Thomas Lockett.....1954

The Harrison Prescott Eddy Medal

The Harrison Prescott Eddy Medal is awarded annually to a member of any Member Association of the Federation for outstanding research contributing in important degree to the existing knowledge of the fundamental principles or processes of sewage treatment, as comprehensively described and published during any stated year in SEWAGE AND INDUSTRIAL WASTES. The award commemorates Harrison Prescott Eddy, a famous engineer and a pioneer in the art of sewage treatment.

Past recipients of the award are:

Harry Willard Gehm.....1943
John Raymond Snell.....1944
Lloyd R. Setter.....1945
H. Heukelekian.....1946
Richard Pomeroy and Fred D. Bowlus.1947
F. W. Kittrell and O. W. Kochtitzky, Jr.....1948
John W. Hood.....1949
Daniel A. Okun.....1950
Peter S. S. Dawson and Samuel H. Jenkins.....1951
George S. Benton, John C. Geyer, Wen-Hsiung Li, and Knut K. Sorteberg..1952
Donald M. Pierce.....1953
William J. Oswald, Harold B. Gotaas, Harvey F. Ludwig, and Victoria Lynch.....1954

* Deceased.

The George Bradley Gascoigne Medal

The George Bradley Gascoigne Medal is awarded annually to a member of any Member Association of the Federation for outstanding contribution to the art of sewage treatment works operation through the successful solution of important and complicated operational problems, as comprehensively described and published during any stated year in SEWAGE AND INDUSTRIAL WASTES. This award is in memory of George Bradley Gascoigne, a prominent consultant from 1922 to 1940, who demonstrated an unusual interest in matters of sewage works operation.

Past recipients of this award are:

Kerwin L. Mick....1943
James T. Lynch and Uhl T. Mann....1944
John D. McDonald....1945
LeRoy Winfield Van Kleeck....1946
Leon S. Kraus....1947
David P. Backmeyer....1948
Wilbur N. Torpey....1949
Clarence E. Keefer....1950
Leonard S. Hillis....1951
Walter Asa Sperry....1952
W. N. Wells and Clarence H. Sherer..1953
Robert Ditmar Bargman....1954

The Charles Alvin Emerson Medal

The Charles Alvin Emerson Medal is awarded annually to a member of any Member Association of the Federation "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Federation of Sewage and Industrial Wastes Associations in such terms as the stimulation of membership, improving standards of operational accomplishments, fostering fundamental research, etc." This award honors Charles Alvin Emerson, who served as President of the Federation from 1928 to 1941 and holds the distinction of being its first Honorary Member.

Past recipients are:

Floyd William Mohlman....1943
Willem Rudolfs....1944
Harold Warner Streeter....1945
F. Wellington Gilcreas....1946
Langdon Pearse....1947
LeRoy Winfield Van Kleeck....1948
William J. Orchard....1949
Morris M. Cohn....1950
Howard Eugene Moses....1951
Frank Woodbury Jones....1952
William D. Hatfield....1953
*Clarence C. Ruchhoft....1954

The Industrial Wastes Medal

The Industrial Wastes Medal was established in 1949 to be awarded annually in the form of a plaque for the most outstanding contribution by an industrial employee on any aspect of industrial wastes control, as published in SEWAGE AND INDUSTRIAL WASTES during the year preceding the award.

Past recipients are:

Roy F. Weston, Robert G. Merman and Joseph G. DeMann....1950
Bruce W. Dickerson....1951
Robert J. Austin, Roy N. Giles, C. T. Nicholson, and F. W. Sciene-man....1952
Richard H. Coe....1953
*N. H. Sanborn....1954

The Kenneth Allen Award

From 1943 through 1948, meritorious personal service to the Member Associations of the Federation was recognized by the Kenneth Allen Award. The award was retired in 1948.

Recipients of this award have been:

1943

Harry Thornton Calvert (ISP)
Edward F. Eldridge (Mich.)
John Kurtz Hoskins (Fed.)
Fred Merryfield (Pac. N.W.)
Edward P. Molitor (N.J.)
Robert S. Phillips (N.C.)
Alfred Henry Weiters (Iowa)
William Homer Wisely (Cen. St.)

* Deceased.

1944

Albert Edward Berry (Can.)
Van Porter Enloe (Ga.)
Albert Legrand Genter (Md.-Del.)
F. Wellington Gilcreas (New Eng.)
Charles A. Holmquist (N.Y.)
Dana Ewart Kepner (Rocky Mtn.)
Leon Benedict Reynolds (Calif.)
Wilson Waldo Towne (Dak.)

1945

Howard Eugene Moses (Pa.)
George S. Russell (Mo.)
Dario Travaini (Ariz.)
Frederick Holman Waring (Ohio)
Joe Williamson, Jr. (Fla.)
Murray Alderson Wilson (Kans.)

1946

E. J. M. Berg (Texas)
Frank E. DeMartini (Fed.)
John R. Downes (N.J.)
Thomas J. Doyle (Mich.)
John Henry Garner (ISP)
Harold Benedict Gotaas (N.C.)
William P. Hughes (Pac. N.W.)
Theodore R. Lovell (Iowa)
George W. Martin (Cen. St.)

1947

William T. Knowlton (Calif.)
Floyd W. Pinney (Dak.)
Gilbert R. Frith (Ga.)
Clarence E. Keefer (Md.-Del.)
Stuart E. Coburn (New Eng.)
Wellington Donaldson (N.Y.)
Henry J. Darcey (Okla.)
Carroll H. Coberly (Rocky Mtn.)
William Storrie (Can.)
William Merriam Cobleigh (Mont.)

1948

George W. Marx (Ariz.)
David Bryon Lee (Fla.)
William Q. Kehr (Mo.)
F. Dean Stewart (Ohio)
Francis deSales Friel (Pa.)

The Arthur Sidney Bedell Award

Established in 1948, the Arthur Sidney Bedell Award acknowledges extraordinary personal service to the Member Associations of the Federation. Each Member Association is privileged once in every three years to name one of its members to receive the award, which may be earned by organizational leadership, administrative service, membership activity, stimulation of technical functions, or similar participation. The award is named for the second President of the Federation, who exemplified its purpose by his long devotion and contribution to the affairs of the New York State Sewage Works Association.

Past recipients follow:

1949

Harry P. Croft (N.J.)
Victor Marcus Ehlers (Texas)
R. Paul Farrell (Ky.-Tenn.)
Carl Edwin Green (Pac. N.W.)
Frederick Leon McDonald (Ark.)
William Thomas Lockett (ISP)
William McKinney Piatt (N.C.)
Walter Asa Sperry (Cen. St.)
Harold Warner Streeter (Fed.)
John L. Strelow (Iowa)

1950

Leland Bradney (Dak.)
John Chester Brigham (N.Y.)
Herbert B. Foote (Mont.)
L. L. Hedgepeth (Va.)
Theodore J. Lafreniere (Can.)
Robert G. McCall (W. Va.)
Edward Alexander Reinke (Calif.)
Frank S. Taylor (Okla.)
LeRoy Winfield Van Kleeck (New Eng.)
William Hugh Weir (Ga.)
Leonard Oliver Williams, Jr. (Rocky Mtn.)
Abel Wolman (Md.-Del.)

1951

Roy Binder (Kans.)
John Clinton Clark (Ala.)
John Raymund Hoffert (Pa.)
John Robertson Hoy (Fla.)
Arthur H. Niles (Ohio)
Charles Henry Trusler (ISE)
Harold W. Yost (Ariz.)
Francis M. Veatch (Mo.)

1952

Don E. Bloodgood (Cen. St.)
Herman Glenn Baity (N.C.)
Paul Bolton (Iowa)
P. N. Daniels (N.J.)
Francis W. Kittrell (Ky.-Tenn.)
Ray E. Koon (Pac. N.W.)
Winfred S. Mahlie (Texas)
Clarence Theodore Mudgett (Mich.)
Walter F. Freeborn (ISP)
Harrison Hale (Ark.)
George Ashby Rhame (S.C.)

1953

Robert James Auld (P. Rico)
Charles G. Caldwell (Rocky Mtn.)
Nathan M. deJarnette (Ga.)
Anthony J. Fischer (N.Y.)
Ralph E. Fuhrman (Md.-Del.)
Quintin B. Graves (Okla.)
John B. Kleven (Dak.)
Douglas L. McLean (Can.)
Walter E. Merrill (N.Eng.)
Fred F. Palmer (Mont.)
Eugene C. Meredith (Va.)
Henry W. Speiden (W.Va.)
Arthur T. Wintersgill (Calif.)

1954

Arthur N. Beck (Ala.)
Merle V. Ellis (Ariz.)
John W. Wakefield (Fla.)
Max Prüss (German)
Gilbert T. Cotterell (ISE)
Leland A. Talbot (Kan.)
Charles A. Haskins (Mo.)
Theodore C. Schaetzle (Ohio)
Bernard S. Bush (Pa.)
Arnold Hoerler (Swiss)

The William D. Hatfield Award

The William D. Hatfield Award recognizes outstanding annual sewage works operation reports. Following the 1946 award, the Board of Control authorized identical awards for outstanding annual reports prepared (I) for plants serving less than 10,000 population, (II) for plants serving populations of 10,000 to 100,000, and (III) for plants serving populations of more than 100,000 persons.

Recipients of this award have been:

1946

Walter M. Kunsch

1947

F. E. Peterson (I)
John R. Szymanski (II)
Warren H. Sleeger and George J. Schroepfer (III)

1948

F. E. Peterson (I)*
Thomas T. Hay (II)
Kerwin L. Mick (III)

1949

Russell D. Craun (I)
George W. Martin (II)
Thomas T. Hay (II)*

1950

William L. Edwards (I)
Walter A. Sperry (II)
John R. Szymanski (II)*
John W. Johnson (III)

1951

William L. Edwards (I)*
J. E. Meers (II)
John R. Szymanski (II)*
George H. Craemer (III)
Kerwin L. Mick (III)*

1952–3

No awards.

1954

Uhl T. Mann (II)
J. E. Meers (II)*
C. W. Christenson (Indus.)

* Previous winner.

Membership Prizes

Prizes for membership activity in its various Member Associations have been awarded by the Federation since 1943. The numerical prize is given to the Member Association having the greatest numerical increase in membership during the year ending September 30 of the award year. The percentage prize is given for the greatest percentage increase in membership during the same period. The following Member Associations have received these prizes:

	Association			*Association*	
Year	*Num.*	*%*	*Year*	*Num.*	*%*
1943	Cen. St.	Fed.	1949	Ohio	Ala.
1944	Cen. St.	Mo.	1950	Iowa	La.
1945	Can.	Ariz.	1951	Mich.	ISE
1946	Can.	Okla.	1952	Cen. St.	Fla.
1947	ISP	Ark.	1953	Calif.	P. Rico
1948	Pa.	W. Va.	1954	Pa.	P. Rico

The Quarter Century Operators' Club

The Quarter Century Operators' Club is an informal group comprising Active or Corporate Members of any Member Association who had been engaged in sewage treatment works operation, on a full-time resident basis, twenty-five years prior to the date of their admission into the Club. The Club was created in 1941 under the sponsorship of Frank Woodbury Jones, who serves as its registrar. The roster:

Harry M. Beaumont
Don E. Bloodgood
Floyd G. Browne
Julius W. Bugbee
Raymond G. Case
E. Sherman Chase
Morris M. Cohn
Rodney E. Cook
P. N. Daniels
Nicholas DeHaas, Sr.
Earl Devendorf
George E. Flower
Harry M. Freeburn
E. D. Fry
G. L. Fugate
Arnold H. Goodman
William P. Gyatt
Wm. C. Hamm
George I. Hanson
William D. Hatfield
Frank W. Jones
Harry J. Krum
Roy S. Lanphear
Carl C. Larson
John V. Lewis
George S. Long
Winfield S. Mahlie
C. D. McGuire
Edwin C. McKeeman
C. T. Mudgett
E. L. Nance
I. H. Nevitt
Arthur H. Niles
Andrew Palmer
John R. Palmer
Wm. M. Piatt
Wm. A. Ryan
Theodore C. Schaetzle
Glenn Searls
Russell S. Smith
Willard R. Smith
H. W. Streeter
Myron W. Tatlock
S. L. Tolman
Henry Van Der Vliet
Edwin B. Wagner
Charles E. Wheeler, Jr.

ANNUAL MEETINGS AND CONVENTIONS

No.	*Location*	*Date*	*No.*	*Location*	*Date*
1	Chicago, Ill.†	Oct. 16, 1928	11	New York, N. Y.†	Jan. 21, 1938
2	New York, N. Y.†	Jan. 18, 1929	12	New York, N. Y.†	Jan. 20, 1939
3	New York, N. Y.†	Jan. 14, 1930	13	New York, N. Y.†	Jan. 18, 1940
4	New York, N. Y.†	Jan. 22, 1931		Chicago, Ill.‡	Oct. 3–5, 1940
5	New York, N. Y.†	Jan. 22, 1932	14	New York, N. Y.†	Jan. 15, 1941
6	New York, N. Y.†	Jan. 19, 1933		New York, N. Y.‡	Oct. 9–11, 1941
7	New York, N. Y.†	Jan. 18, 1934	15	Cleveland, Ohio§	Oct. 22–24, 1942
8	New York, N. Y.†	Jan. 18, 1935	16	Chicago, Ill.§	Oct. 21–23, 1943
9	New York, N. Y.†	Jan. 16, 1936	17	Pittsburgh, Pa.§	Oct. 12–14, 1944
10	New York, N. Y.†	Jan. 22, 1937	18	Chicago, Ill.†	Oct. 17–18, 1945

† Annual business meeting of Board of Control.
‡ Convention of membership-at-large.
§ Annual business meeting of Board of Control and convention of membership-at-large.

No.	*Location*	*Date*	*No.*	*Location*	*Date*
19	Toronto, Ont., Can.§	Oct 7–9, 1946	23	Washington, D. C.§	Oct. 9–12, 1950
20	Philadelphia, Pa.†	Oct. 10, 1947	24	St. Paul, Minn.§	Oct. 8–11, 1951
	San Francisco, Calif.‡	Jul. 21–4, 1947	25	New York, N. Y.§	Oct. 6–9, 1952
21	Detroit, Mich.§	Oct. 18–21, 1948	26	Miami, Fla.§	Oct. 13–16, 1953
22	Boston, Mass.§	Oct. 17–20, 1949	27	Cincinnati, Ohio §	Oct. 11–14, 1954

DIRECTORY OF COMMITTEES

1954–55

Constitutional Committees

(*See Article VI of By-laws*)

EXECUTIVE COMMITTEE OF THE BOARD OF CONTROL

D. B. Lee, *Chairman*

L. J. Fontenelli
G. W. Martin
Nicol MacNicol
W. S. Wise
E. C. Jensen
W. A. Hardenbergh

PUBLICATIONS COMMITTEE

The Publications Committee arranges the technical programs for the annual conventions of the Federation and has general supervision of all publications of the Federation.

Rolf Eliassen, *Chairman*

A. J. Fischer, *Vice-Chairman*

F. W. Gilcreas
L. L. Hedgepeth
R. W. Hess
L. S. Kraus
F. W. Mohlman
D. B. Smith
G. E. Symons
R. E. Fuhrman

ORGANIZATION COMMITTEE

The Organization Committee examines and reports to the Board on applications for membership in the Federation and endeavors to encourage the formation of new regional associations or conferences eligible for membership.

Seth G. Hess, *Chairman*

Richard Hazen
J. W. Wakefield

SEWAGE AND INDUSTRIAL WASTES PRACTICE COMMITTEE

The Sewage and Industrial Wastes Practice Committee reviews and directs for publication any resolution, report, or publication which establishes professional or technical standards in the name of the Federation. The following Manuals of Practice have been published under the direction of the committee:

No. 1—Occupational Hazards in Sewage Works (1944)
No. 2—Utilization of Sewage Sludge as Fertilizer (1946)
No. 3—Municipal Sewer Ordinances (1949)
No. 4—Chlorination of Sewage and Industrial Wastes (1951)
No. 5—Air Diffusion in Sewage Works (1952)

Morris M. Cohn, *Chairman*

D. E. Bloodgood, *Vice-Chairman*

T. W. Clapham
E. B. Cobb
C. E. Keefer
Kerwin L. Mick
F. W. Mohlman
H. E. Orford
Langdon Pearse
D. M. Pierce
L. W. Van Kleeck
F. M. Veatch
R. E. Fuhrman

Subcommittee on Sewer Maintenance

This subcommittee of the Sewage and Industrial Wastes Practice Committee has been directed to develop a Manual of Practice on "Maintenance of Sewers and Appurtenant Structures." The first draft of the manual is in preparation.

T. W. Clapham, *Chairman*

A. A. Appel, *Vice-Chairman*

N. S. Bubbis	M. B. Nixon	Sydney Preen
H. J. Graeser	G. M. Olewiler	C. S. Seabrook
J. L. Klamm		L. E. West

Subcommittee on Standardization of Units

This subcommittee of the Sewage and Industrial Wastes Practice Committee has been assigned to develop an approved schedule of units to be used in the reporting of plant operation and laboratory data. A committee of about forty members is engaged in revising a preliminary draft.

H. E. Orford, *Chairman*

Subcommittee on Trickling Filters

This subcommittee of the Sewage and Industrial Wastes Practice Committee is engaged in the development of a Manual of Practice to be entitled "Trickling Filters—Their Characteristics and Loadings."

Kenneth V. Hill, *Chairman*

B. F. Hatch W. S. Mahlie

Wm. E. Stanley

Subcommittee on Sewage Works Accounting

This subcommittee was created in 1946 for the purpose of developing a Manual of Practice on accounting procedures for municipal sewage works functions. Mimeographed copies of the manual in tentative form were made available for purchase in April, 1949.

F. M. Veatch, *Chairman*

G. J. Beiswanger	E. A. Farmer	K. K. Wallace
Alfred A. Estrada		S. I. Zack

Subcommittee on Paints and Protective Coatings

This subcommittee has the function of assembling experience and data on paints and protective coatings used in sewage works, to be presented with recommendations in the form of a manual. The subcommittee was created in 1946 and the first draft of the manual is now being prepared for critical review.

Kerwin L. Mick, *Chairman*

Virgil Anderson	W. T. McClenahan	F. W. Pinney
J. W. Johnson		M. L. Robins
L. S. Kraus		Walter A. Sperry

Subcommittee on Vacuum Filtration of Sludge

This subcommittee was created in 1951 for the purpose of developing a Manual of Practice on vacuum filtration of sewage sludge.

E. B. Cobb, *Chairman*

J. D. McDonald W. E. Stanley L. W. Van Kleeck

Subcommittee on Operation of Sewage Plants

This subcommittee was created in 1953 for the purpose of developing a Manual of Practice on sewage plant operation.

D. M. Pierce, *Chairman*

A. P. Troemper, *Vice-Chairman*

S. T. Barker
Ben Benas
W. M. Bingley
D. E. Bloodgood
P. N. Daniels
E. F. Eldridge
F. W. Jones
L. S. Kraus
W. S. Mahlie
A. H. Niles
H. G. Rogers
G. E. Symons
L. W. Van Kleeck
R. E. Fuhrman

Subcommittee on Sewage Treatment Plant Design

The following Federation representatives were appointed in 1953 to serve jointly with representatives of the American Society of Civil Engineers in the production of a manual of practice.

N. E. Anderson M. H. Klegerman G. W. Martin
T. R. Haseltine C. L. Palmer

Subcommittee on Storm and Sanitary Sewer Design

The following Federation representatives were appointed in 1953 to serve jointly with representatives of the American Society of Civil Engineers in the production of a manual of practice.

C. G. Gaither L. L. Sphar C. R. Velzy
H. S. Smith S. I. Zack

Research Committee

The Research Committee has the function of stimulating research work among the various Member Associations, and of cooperating with other organizations in the promotion of research.

H. Heukelekian, *Chairman*

H. E. Orford, *Vice-Chairman*

D. E. Bloodgood
N. S. Chamberlin
G. P. Edwards
M. B. Ettinger
I. Gellman
R. D. Hoak
R. S. Ingols
P. W. Kabler
Max Katz
R. R. Kountz
R. M. Manganelli
P. H. McGauhey
W. A. Moggio
W. Allen Moore
R. C. Palange
G. A. Rohlich
L. R. Setter
D. B. Smith
H. A. Trebler
L. W. Van Kleeck

Subcommittee on Toxicity of Industrial Wastes

This subcommittee of the Research Committee is functioning in three sections:

Section I. Critical review of literature; P. Doudoroff, *Chairman*, C. E. Barnes, H. Heukelekian, G. P. Edwards, F. W. Kittrell, C. E. Renn and R. F. Weston.

Section II. Development of methods for toxicity determinations on wastes; R. S. Ingols, *Chairman*, H. E. Babbitt, D. E. Bloodgood, M. L. Granstrom, T. Jaffee, R. R. Kountz, N. L. Nemerow, M. L. Robinson, W. W. Sanderson, C. N. Sawyer and J. H. Sorrels.

Section III. Development and standardization of bio-assay methods; P. Doudoroff, *Chairman*, B. G. Anderson, G. E. Burdick, P. S. Galtsoff, W. B. Hart, R. Patrick, E. R. Strong, E. W. Surber and W. M. Van Horn.

Subcommittee on Research Projects

H. Heukelekian, *Chairman*, L. Chambers, R. Eliassen, I. Gerring, R. D. Hoak, H. C. Marks, V. G. McKenzie, C. Morris, C. Renn and C. N. Sawyer.

Finance Committee

The Finance Committee develops the annual operating budget of the Federation and affords guidance to the Board of Control in financial affairs.

W. J. Orchard, *Chairman*

L. J. Fontenelli

D. B. Lee

Committee on Standard Methods of Sewage and Industrial Wastes Analysis

Created by the Board of Control on January 22, 1931, the Committee on Standard Methods of analysis was given constitutional status in October, 1953. The committee develops, perfects and modifies standard methods for the analysis of sewage and industrial wastes and of sludges or by-products therefrom. It also functions with similar committees of the American Water Works Association and American Public Health Association in the production of the laboratory manual *Standard Methods for the Examination of Water and Sewage*, the tenth edition of which was published early in 1955.

G. P. Edwards, *Chairman*

R. S. Ingols, *Vice-Chairman*

L. D. Betz
D. E. Bloodgood
A. M. Buswell
N. S. Chamberlin
R. V. Day
W. E. Dobbins
K. Frashina
M. Ginn
C. F. Gurnham
W. D. Hatfield
L. L. Hedgepeth
W. L. Henderson
H. Heukelekian
R. D. Hoak
E. F. Hurwitz
J. E. Kinney
R. R. Kountz
J. B. Lackey
V. Langworthy
G. W. Lawton
W. S. Mahlie
H. C. Marks
W. Maske
R. G. McCall
J. A. McCarthy
M. G. Mellon
W. A. Moore
J. C. Morris
N. L. Nemerow
M. S. Nichols
R. Pomeroy
M. L. Robins
W. W. Sanderson
C. N. Sawyer
L. R. Setter
R. F. Weston

Special Committees

Committee on Awards

The Committee on Awards was created by the Board of Control on October 11, 1941. Functions of the committee are to advise the Board on matters of award procedures and to make recommendations as to the annual winners of the Eddy, Gascoigne, Emerson, and Industrial Wastes medals.

Philip F. Morgan, *Chairman*

R. D. Bargman
R. E. Stiemke

Honorary Membership Committee

Authorized by the Board of Control on October 24, 1942, this committee comprises the President and four latest, living Past Presidents with the senior Past President as chairman. The committee reviews nominations for election to the grade of Honorary Member and makes recommendations to the Board on such nominations.

R. E. Fuhrman, *Chairman*

Earnest Boyce
E. Sherman Chase
L. J. Fontenelli
D. B. Lee

Operation Reports Committee

The Operation Reports Committee was created by the Board of Control on October 11, 1941, to provide for Federation recognition of outstanding operation reports. The committee now administers the annual William D. Hatfield Award.

M. E. Dawkins, *Chairman*

G. F. Bernauer
W. M. Bingley
W. D. Hatfield
C. W. Klassen

Operator's Qualifications Committee

Authorized by the Board of Control on October 11, 1941, the Operator's Qualifications Committee is assigned to "establish minimal qualifications for operators of various classes of treatment works." The committee also has the duty of collecting and compiling data on present procedures in the licensing and certification of operators for reference to Member Associations.

W. M. Bingley, *Chairman*

W. T. Ballard
Benjamin Benas
T. C. Schaetzle
Sol Seid

Industrial Wastes Committee

The Industrial Wastes Committee was created by the Board of Control on October 23, 1943, for the purpose of developing interest in this important field and to direct a program whereby the Federation may be of service in industrial waste problems.

R. W. Hess, *Chairman*

K. S. Watson, *Vice-Chairman*

R. R. Balmer
E. B. Besselievre
H. H. Black
D. E. Bloodgood
J. M. Brown, Jr.
H. W. Gehm
F. Gurnham
W. B. Hart
E. A. Leonard
R. W. Ockershausen
L. F. Oeming
G. A. Pettit
H. T. Reuning
C. N. Sawyer
W. S. Wise

Nominating Committee

The special Nominating Committee was created by the Board of Control on October 9, 1946, to function in an advisory capacity to the Election Committee. The Nominating Committee is to comprise the last five living Past Presidents, with the senior Past President as chairman.

A. H. Niles, *Chairman*

Earnest Boyce
E. Sherman Chase
L. J. Fontenelli
R. E. Fuhrman

Quarter Century Operators' Club Committee

The special Quarter Century Operators' Club Committee was created by the Board of Control on October 9, 1946. It is the function of this Committee to establish eligibility requirements, process membership applications, maintain the roster, and supervise the activities of the Quarter Century Operators' Club.

H. Van Der Vliet, *Chairman*

A. H. Niles
Harold W. Streeter

Legislative Analysis Committee

The Legislative Analysis Committee was created by the Board of Control on October 17, 1945, to study legislation pertinent to the interests of the Federation and to serve the Board in advisory capacity.

R. S. Shaw, *Chairman*

J. H. Allen
V. W. Bacon
W. W. Gillespie
M. LeBosquet
R. L. Winget

Constitution and By-Laws Committee

The Constitution and By-Laws Committee was created by the Board of Control on October 10, 1947, to review and develop recommendations for the amendment of the Constitution and By-Laws of the Federation as may be deemed advisable under changing conditions.

C. A. Emerson, *Chairman*

F. S. Friel
W. J. Orchard
B. A. Poole
G. S. Russell

Safety Committee

This committee was created in 1954 for the purpose of maintaining close liaison between the Federation and the National Safety Council in the fields common to both organizations.

J. J. Wirts, *Chairman*

G. L. Burt
U. T. Mann
W. W. Mathews
H. A. Schreiber
L. W. Van Kleeck

Joint Committees With Other Associations

(Also see Sewage and Industrial Wastes Practice Committee)

Joint Committee on Advancement of Sanitary Engineering

On October 5, 1952 the Board of Control authorized participation in the Joint Committee on Advancement of Sanitary Engineering with the American Society of Civil Engineers, American Water Works Association, American Public Health Association, and American Society for Engineering Education. The objectives of the committee are to study professional recognition of sanitary engineers, educational and training requirements, functional use in public health and military service, opportunities for employment, and similar matters.

FSIWA Representatives

R. E. Lawrence D. F. Metzler R. S. Rankin

Joint Committee on Chlorine Supply

On October 11, 1951, the Board of Control authorized participation in the Joint Committee on Chlorine Supply with the American Water Works Association and the Conference of State Sanitary Engineers. The objective of the committee is to study problems of chlorine supply and distribution in the water and sewage fields, and to develop recommendations for their solution.

FSIWA Representatives

L. H. Enslow L. L. Hedgepeth

Policy Advisory Committee, APHA Engineering Section

This joint committee was created in 1947 to advise the Council of the Engineering Section, American Public Health Association, on policies and activities of the Section relating to the field of environmental sanitation. Representation on the committee is held by national, regional, and state public health and sanitary engineering organizations.

FSIWA Representative

B. A. Poole

Joint Policy Committee

This joint committee was created in 1954 to provide a unified approach to problems or actions arising by reasons of emergencies or in the common interest. Representation on the committee is held by the Federation, the American Water Works Association, and the Water and Sewage Works Manufacturers' Association.

FSIWA Representatives

E. Sherman Chase L. J. Fontenelli R. E. Fuhrman
C. A. Emerson D. B. Lee

Special Convention Committees

Convention Management Committee

The function of this committee is to supervise details of the management of the Annual Meetings of the Federation.

T. T. Quigley, *Chairman*

H. E. Schlenz
J. G. Stewart
H. Van Der Vliet
R. E. Fuhrman

Meeting Place Committee

This committee reviews invitations received for the Annual Meetings of the Federation and makes recommendations to the Board of Control in regard to the time and place of such meetings.

D. B. Lee, *Chairman*

L. J. Fontenelli
H. S. Howe
G. W. Martin
R. S. Rankin
J. G. Stewart
R. E. Fuhrman

Membership Lists

SUMMARY OF MEMBERSHIP

(As of December 31, 1954)

Federation Members

Honorary Members	14
Associate Members	68
Member Associations	38
Active Members	6,101
Corporate Members	163

Net Membership of Member Associations *

Member Association	Active	Honorary	Corporate	Total
Alabama	32	—	2	34
Arizona	41	—	4	45
Arkansas	64	—	—	64
California	543	1	8	552
Canadian Inst.	421	1	1	423
Central States	593	3	28	624
Dakota	31	—	—	31
Federal	84	1	—	85
Florida	182	—	—	182
Georgia	53	—	—	53
Germany	37	1	—	38
Iowa	118	—	—	118
ISE (England)	26	—	—	26
ISP (England)	132	1	—	133
Kansas	100	—	—	100
Kentucky-Tennessee	106	—	3	109
Louisiana	9	—	—	9
Maryland-Delaware	62	—	—	62
Michigan	315	—	—	315
Missouri	37	—	2	39
Montana	30	—	5	35
Nebraska	35	—	4	39
New England	350	2	—	352
New Jersey	230	1	—	231
New York	610	1	17	628
North Carolina	121	—	—	121
Ohio	302	—	35	337
Oklahoma	51	—	—	51
Pacific Northwest	276	—	—	276
Pennsylvania	486	2	31	519
Puerto Rico	48	—	—	48
Rocky Mountain	75	—	—	75
South Carolina	45	—	2	47
Sweden	73	—	—	73
Swiss	15	—	—	15
Texas	202	—	1	203
Virginia	93	—	14	107
West Virginia	73	—	6	79
Totals	6,101	14	163	6,278

* Not including Dual Members

MEMBER ASSOCIATIONS

Alabama Water and Sewage Association—Sewage Works Section (Affiliated 1948).

Territory: State of Alabama.
President: C. Lamon; *Vice-President:* C. L. Gray; *Director:* J. L. Crockett, Jr.; *Treasurer:* L. Hubbs; *Secretary:* W. L. Samuel, Alabama Polytechnic Inst., Auburn, Ala.

Arizona Sewage and Water Works Association—Sewage Works Section (Affiliated 1928).

Territory: State of Arizona.
President: P. J. Martin, Jr.; *First Vice-President:* G. T. Rederdre; *Second Vice-President:* M. V. Ellis; *Director:* L. O. Gardner; *Secretary-Treasurer:* Quentin M. Mees, 721 N. Olsen, Tucson, Ariz.

Arkansas Water and Sewage Conference—Sewage Works Section (Affiliated 1946).

Territory: State of Arkansas.
Chairman: A. O. Chastain; *Vice-Chairman:* L. J. Embree; *Director:* G. T. Kellogg; *Secretary-Treasurer:* Harrison Hale, c/o Southern State College, Magnolia, Ark.

California Sewage and Industrial Wastes Association (Affiliated 1928).

Territory: State of California.
President: A. A. Appel; *First Vice-President:* H. B. Foster, Jr.; *Second Vice-President:* E. V. Quartly; *Director:* F. G. Nelson; *Secretary-Treasurer:* J. C. Mallery, 4822 N. Dunsmore Ave., La Crescenta, Calif.

Canadian Institute on Sewage and Sanitation (Affiliated 1933).

Territory: Dominion of Canada.
President: N. S. Bubbis; *Vice-President:* C. G. R. Armstrong; *Director:* N. MacNicol; *Secretary-Treasurer:* A. E. Berry, Ontario Dept. of Health, Parliament Buildings, Toronto 8, Ont., Can.

Central States Sewage and Industrial Wastes Association (Affiliated 1928).

Territory: States of Illinois, Indiana, Wisconsin, and Minnesota.
President: O. J. Muegge; *First Vice-President:* A. J. Duvall; *Second Vice-President:* W. E. Ross; *Third Vice-President:* A. P. Troemper; *Director:* M. L. Robins; *Secretary-Treasurer:* George F. Bernauer, 713 Chapman St., Madison, Wis.

Dakota Water and Sewage Works Conference—Sewage Works Sections (Affiliated 1936).

North Dakota Section

Territory: State of North Dakota.
President: P. Hays; *Vice-President:* E. Ostlie; *Director:* R. J. Stapf; *Secretary-Treasurer:* Jerome H. Svore, c/o State Dept. of Health, Bismarck, N. Dak.

South Dakota Section

Territory: State of South Dakota.
President: S. Bies; *Vice-President:* C. Clark; *Director:* R. J. Stapf; *Secretary-Treasurer:* Charles E. Carl, c/o Div. of Sanitary Engineering, State Board of Health, Pierre, S. Dak.

Federal Sewage Research Association (Affiliated 1930).

Territory: Federal employees wherever stationed.
President: S. C. Martin; *Vice-President:* P. Douderoff; *Director:* L. B. Dworsky; *Secretary-Treasurer:* Keith S. Krause, Room 4212A, South H E W Bldg., Washington 25, D. C.

Florida Sewage and Industrial Wastes Association (Affiliated 1941).

Territory: State of Florida.
President: P. Flanagan; *Vice-President:* C. E. Richheimer; *Director:* J. E. Kiker, Jr.; *Secretary-Treasurer:* M. E. Dawkins, P. O. Box 210, Jacksonville 1, Fla.

Georgia Water and Sewage Association—Sewage Works Section (Affiliated 1936).

Territory: State of Georgia.
President: F. Lamb; *First Vice-President:* W. W. Kiser; *Second Vice-President:* F. L. Futral; *Director:* C. E. Drummond; *Secretary-Treasurer:* A. T. Storey, 1210 Hemphill Ave., N.W., Atlanta, Ga.

German Sewage Technologists Association (Affiliated 1950).
(Abwassertechnische Vereinigung)

Territory: Western Germany.
President: F. Schreier; *Vice-President:* M. Prüss; *Director:* F. Sierp; *Secretary-Treasurer:* O. Pallasch, Theaterstrasse 24, Bonn, Germany.

Institute of Sewage Purification—England (Affiliated 1932).

Territory: British Empire.
President: A. Key; *Vice-President:* H. Taylor; *Director:* W. F. Freeborn; *Secretary:* W. F. Freeborn, 34 Cardinal's Walk, Hampton-on-Thames, Middlesex, England.

Institution of Sanitary Engineers—England (Affiliated 1932).

Territory: British Empire.
President: J. T. Calvert; *Vice-President:* N. J. Tatman; *Director:* W. F. Brown; *Treasurer:* A. Sciver; *Secretary:* Ernest V. Balsom, 118 Victoria St., Westminster, S. W. 1, London, England.

Iowa Sewage Works Association (Affiliated 1928).

Territory: State of Iowa.
President: L. Holtcamp; *Vice-President:* V. Garwood; *Director:* H. S. Smith; *Secretary-Treasurer:* L. F. Skorczeski, 207 South 15th Ave., Marshalltown, Iowa.

Kansas Sewage and Industrial Wastes Association (Affiliated 1935).

Territory: State of Kansas.
Chairman: L. Cunningham; *Vice-Chairman:* L. Beyer; *Director:* M. Nelson; *Secretary-Treasurer:* Robert H. Hess, Supt. of Water and Sewage Treatment, City Building, Wichita 2, Kans.

Kentucky-Tennessee Industrial Wastes and Sewage Works Association (Affiliated 1946).

Territory: States of Kentucky and Tennessee.
Chairman: R. P. Johnson; *Vice-Chairman:* C. M. Davidson; *Director:* F. W. Kittrell; *Secretary-Treasurer:* S. Leary Jones, 420 Sixth Ave., N., Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage—Sewage Works Section (Affiliated 1949).

Territory: State of Louisiana.
Chairman: J. L. Love; *Vice-Chairman:* R. L. Lawrence; *Director:* J. J. Holtgreve; *Secretary-Treasurer:* George H. West, P. O. Box 15, Lake Charles, La.

Maryland-Delaware Water and Sewerage Association—Sewage Works Section (Affiliated 1928).

Territory: States of Maryland and Delaware.
President: E. F. Donaldson; *First Vice-President:* R. L. Nichols; *Second Vice-President:* F. F. O'Connor; *Director:* R. H. Ritter; *Secretary-Treasurer:* W. M. Bingley, 2411 N. Charles St., Baltimore 18, Md.

Michigan Sewage and Industrial Wastes Association (Affiliated 1930).

Territory: State of Michigan.
President: H. M. Leonhard; *First Vice-President:* F. W. DuBois; *Second Vice-President:* H. McEntee; *Director:* C. L. Palmer; *Secretary-Treasurer:* D. M. Pierce, Michigan Dept. of Health, Room 334, Administration Bldg., Lansing 4, Mich.

Missouri Water and Sewerage Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Missouri.
Chairman: C. S. Smith; *Vice-Chairman:* E. G. Lee; *Director:* J. K. Smith; *Secretary-Treasurer:* Warren A. Kramer, c/o State Office Bldg., Sixth Floor, Jefferson City, Mo.

Montana Sewage and Industrial Wastes Association (Affiliated 1944).

Territory: State of Montana.
Chairman: D. Anderson; *Vice-Chairman:* M. F. Dixon; *Director:* F. F. Palmer; *Secretary-Treasurer:* Harvey W. Taylor, Morrison & Maierle, Inc., Helena, Mont.

Nebraska Sewage and Industrial Wastes Association (Affiliated 1952).

Territory: State of Nebraska.
President: E. E. Borden; *Vice-President:* W. F. Rapp, Jr.; *Director:* T. A. Filipi; *Secretary-Treasurer:* V. J. Lechtenberg, 614 Standard Oil Bldg., Omaha, Nebr.

New England Sewage and Industrial Wastes Association (Affiliated 1929).

Territory: States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island.
President: W. E. Merrill; *First Vice-President:* J. H. L. Giles; *Second Vice-President:* C. N. Sawyer; *Director:* W. S. Wise; *Secretary-Treasurer:* Henry F. Munroe, 75 Paine Ave., Cranston 10, R. I.

New Jersey Sewage and Industrial Wastes Association (Affiliated 1942).

Territory: State of New Jersey.
President: J. W. Hood; *First Vice-President:* J. W. Collom; *Second Vice-President:* A. Palmer; *Director:* S. Seid; *Secretary-Treasurer:* Michael S. Kachoraky, P. O. Box 766, Manville, N. J.

New York Sewage and Industrial Wastes Association (Affiliated 1930).

Territory: State of New York.
President: W. L. Edwards; *Vice-President:* C. E. Irving; *Director:* A. J. Fischer; *Treasurer:* J. C. Brigham; *Secretary:* R. C. Sweeney, c/o State Dept. of Health, 21 N. Broadway, White Plains, N. Y.

North Carolina Sewage and Industrial Waste Association (Affiliated 1929).

Territory: State of North Carolina.
Chairman: S. E. Harris; *Vice-Chairman:* R. S. Phillips; *Director:* P. D. Davis; *Secretary-Treasurer:* W. E. Long, Jr., Box 2091, Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conference (Affiliated 1932).

Territory: State of Ohio.
Chairman: W. D. Sheets; *First Vice-Chairman:* G. A. Pettit; *Second Vice-Chairman:* F. Ruck; *Director:* G. A. Hall; *Secretary-Treasurer:* Ward E. Conrad, 301 Ohio Depts. Bldg., Columbus 15, Ohio.

Oklahoma Water, Sewage and Industrial Waste Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Oklahoma.
President: M. A. Buercklin, Jr.; *Vice-President:* W. C. Douce; *Director:* C. E. Moutrey; *Secretary-Treasurer:* John P. Smouse, State Dept. of Health, 3400 N. Eastern, Oklahoma City 5, Okla.

Pacific Northwest Sewage and Industrial Wastes Association (Affiliated 1933).

Territory: States of Washington, Oregon, and Idaho.
President: F. Merryfield; *Vice-President:* E. F. Eldridge; *Director:* E. C. Jensen; *Secretary-Treasurer:* Walter W. Saxton, 408 Old Capitol Bldg., Olympia, Wash.

Pennsylvania Sewage and Industrial Wastes Association (Affiliated 1928).

Territory: State of Pennsylvania.
President: G. J. Wiest; *First Vice-President:* L. L. Gwin; *Second Vice-President:* G. A. Elias; *Director:* H. T. Reuning; *Secretary-Treasurer:* B. S. Bush, c/o Pennsylvania Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Association (Affiliated 1947).

Territory: Puerto Rico.
President: E. F. Saavedro; *Vice-President:* R. Bras; *Director:* L. R. Robles; *Secretary-Treasurer:* Robert J. Auld, c/o Puerto Rico Aqueduct and Sewer Authority, Box 2832, San Juan 12, Puerto Rico.

Rocky Mountain Sewage Works Association (Affiliated 1947).

Territory: States of Wyoming, Colorado, and New Mexico.
President: W. F. Turner; *Vice-President:* R. L. Streeter; *Director:* B. V. Howe; *Secretary-Treasurer:* John R. Peterson, 376 City and County Bldg., Denver 2, Colo.

South Carolina Water and Sewage Works Association—Sewage Works Section (Affiliated 1949).

Territory: State of South Carolina.
Chairman: J. D. Spence; *Vice-Chairman:* J. D. Lesslie; *Director:* T. E. Robertson, Jr.; *Secretary-Treasurer:* T. A. Kolb, 1329 Ellison Rd., Columbia, S. C.

Swedish Association for Water Hygiene (Affiliated 1952).
(Föreningen För Vattenhygien)

Territory: Sweden.
President: S. Vallin; *Vice-President:* N. O. Heinertz; *Director:* N. Westberg; *Secretary-Treasurer:* Erik Jonsson, Box 5038, Stockholm 5, Sweden.

Swiss Association of Water and Sewage Professionals (Affiliated 1947).
(Verband Schweizerischer Abwasserfachleute)

Territory: Switzerland.
President: F. Baldinger; *Vice-President:* A. Hoerler; *Director:* P. Wildi; *Treasurer:* E. Holinger; *Secretary:* Pierre Wildi, Hegenmatt 28, Zurich, Switzerland.

Texas Water and Sewage Works Association—Sewage and Industrial Wastes Section (Affiliated 1928).

Territory: State of Texas.
Chairman: K. E. Mills; *First Vice-Chairman:* W. S. Mahlie; *Second Vice-Chairman:* G. A. Doty; *Director:* C. H. Connell; *Secretary:* V. M. Ehlers, 2202 Indian Trail, Austin, Tex.; *Assistant Secretary and Treasurer:* Mrs. E. H. Goodwin.

Virginia Industrial Wastes and Sewage Works Association (Affiliated 1947).

Territory: State of Virginia.
President: F. H. Miller; *Vice-President:* L. R. Albert; *Director:* B. L. Strother; *Secretary-Treasurer:* J. L. Hamrick, Jr., 415 W. Franklin St., Richmond 20, Va.

West Virginia Sewage and Industrial Wastes Association (Affiliated 1947).

Territory: State of West Virginia.
President: O. C. Thompson; *First Vice-President:* T. K. Bruce; *Second Vice-President:* J. W. Lester; *Director:* H. K. Gidley; *Secretary-Treasurer:* Glen O. Fortney, State Dept. of Health, Charleston 5, W. Va.

HONORARY MEMBERS

Berry, Albert E. (1954), Director, Ontario Dept. of Health, San. Eng. Div., 235 Gainsboro Rd., Toronto 8, Ont., Can.

Bugbee, Julius W. (1942), 246 Lowell Ave., Providence 9, R. I.

DeBerard, Wilford Willis (1950), Dep. Commr. of Water and Ch. Water Engr., Bur. of Eng., Dept. of Pub. Works, 402 City Hall, Chicago 2, Ill.

Emerson, Charles A. (1941), Cons. Engr., Havens & Emerson, Woolworth Bldg., New York 7, N. Y.

Gilcreas, F. Wellington (1948), Asst. Dir., Div. of Lab. & Research, State Dept. of Health, New Scotland Ave., Albany 1, N. Y.

Hyde, Charles Gilman (1943), Cons. Engr., 2495 Shattuck Ave., Berkeley 4, Calif.

Imhoff, Karl (1953), Cons. Engr., Robert Schmidt Str. 8, Essen, Germany.

Lockett, William T. (1954), Chief Chemist, Middlesex County Main Drainage Works, Oak Lane, Isleworth, Middlesex, Eng.

Mohlman, Floyd W. (1944), Dir., Div. of Lab., Sanitary Dist. of Chicago, 910 S. Michigan Ave., Chicago 5, Ill.

Moses, Howard E. (1943), Cons. Engr., State Dept. of Health, 1522 N. Second St., Harrisburg, Pa.

Orchard, William J. (1946), Gen. Mgr., Wallace & Tiernan Co., Inc., Newark 1, N. J.

Pearse, Langdon (1942), Sanitary Engr., Sanitary Dist. of Chicago, 910 S. Michigan Ave., Chicago 5, Ill.

Rudolfs, Willem (1945), Huzarenlaan, Joppe (Geld), The Netherlands.

Streeter, Harold W. (1953), Box 192, R.R.1, Old Indian Hill Rd., Cincinnati 27, Ohio.

ASSOCIATE MEMBERS

ACF Industries, Inc., 1501 E. Ferry Ave., Detroit 11, Mich., Rep. William A. Gormley, Sales Mgr., Valve Div.

Airkem, Inc., 241 East 44th St., New York 17, N. Y., Rep. J. M. von Bergen.

American Cast Iron Pipe Co., Birmingham, Ala., Rep. E. L. Gilder.

American City Magazine, 470 Fourth Ave., New York, N. Y., Rep. Edgar J. Buttenheim, Pres.

American Concrete Pipe Assn., 228 N. LaSalle St., Suite 1033, Chicago 1, Ill., Rep. Howard F. Peckworth, Managing Dir.

American Well Works, 100 N. Broadway, Aurora, Ill., Rep. L. H. Kramer, Exec. Vice-Pres.

Armco Drainage & Metal Products, Inc. (Armco Steel Corp.), Middletown, Ohio, Rep. W. H. Spindler, Pub. Mgr.

B-I-F Industries, Inc., 345 Harris Ave., Providence, R. I., Rep. G. W. Kelsey, Vice-Pres.

Carter, Ralph B., Co., 192 Atlantic St., Hackensack, N. J., Rep. J. J. Horgan.

Chain Belt Co., Milwaukee 4, Wis., Rep. W. B. Marshall.

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass., Rep. John H. Sheehan.

Chicago Pump Co., 622 Diversey Parkway, Chicago 14, Ill., Rep. Milton Spiegel, Vice-Pres.

Climax Engine & Pump Mfg. Co., 208 N. LaSalle St., Chicago 4, Ill., Rep. E. D. West, Mgr.

Combustion Engineering, Inc., Raymond Pulverizer Div., 1315 N. Branch St., Chicago 22, Ill., Rep. C. W. Gordon, Mgr.

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill., Rep. J. W. Bowe.

Dorr Co., Barry Pl., Stamford, Conn.

Elmco Corp., 301 S. Hicks Rd., Palatine, Ill., Rep. Paul O. Richter, Mgr., Central Div.

Engineering News-Record, 330 W. 42nd St., New York 36, N. Y.

Everson Mfg. Co., 214 W. Huron St., Chicago 10, Ill., Rep. R. B. Everson, Pres.

Fairbanks, Morse & Co., 80 Broad St., New York 4, N. Y., Rep. Charles J. Prestler, Mgr., Pump Sales.

Fischer & Porter Co., Hatboro, Pa., Rep. Jack Burke.

Flexible Sales Corp., 3786 Durango Ave., Los Angeles 34, Calif., Rep. Peter L. Ciaccio, Mgr.

Foxboro Co., Util. Ind. Div., Foxboro, Mass., Rep. Russell H. Babcock, Asst. Mgr.

Gale Oil Separator Co., 52 Vanderbilt Ave., New York 17, N. Y., Rep. William A. Gehle, Pres.

General Electric Co., 1 River Rd., Schenectady 5, N. Y., Rep. E. O. Potthoff.

General Laboratory Supply Co., 320 Market St., Paterson 3, N. J., Rep. I. T. Klein.

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis 6, Mo., Rep. William P. Greundler.

Hardinge Co., York, Pa., Rep. M. C. Fleming.

Hersey Mfg. Co., Corner of E. and Second Sts., S. Boston 27, Mass., Rep. William C. Sherwood.

Homestead Valve Mfg. Co., Box 348, Coraopolis, Pa., Rep. F. E. Schuchman.

Industrial Materials Co., Somerset St. & Trenton Ave., Philadelphia 34, Pa., Rep. John M. Riordan, Pres.

Inertol Co., Inc., 480 Frelinghuysen Ave., Newark 5, N. J., Rep. G. W. Rupp.

Infilco Inc., 2750 12th Ave., S., Tucson, Ariz., Rep. H. W. Gillard.

Jeffrey Mfg. Co., Columbus 16, Ohio, Rep. S. L. Tolman.

Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y., Rep. R. F. Orth.

Josam Mfg. Co., Michigan City, Ind., Rep. Leo N. Newman.

Komline-Sanderson Eng. Corp., P. O. Box 257, Peapack, N. J., Rep. T. R. Komline, Pres.

Lakeside Eng. Corp., 222 W. Adams St., Chicago 6, Ill., Rep. R. O. Friend.

Limestone Products Corp. of America, Newton, N. J., Rep. Howard N. Stark.

Link-Belt Co., Colmar Plant, Colmar, Pa., Rep. B. K. Hartman.

Lock Joint Pipe Co., E. Orange, N. J., Rep. F. F. Longley, Vice-Pres.

Mathieson Chemical Corp., Mathieson Bldg., 10 Light St., Baltimore 3, Md., Rep. Keith MacLeod.

Mine Safety Appliances Co., Braddock, Thomas & Meade Sts., Pittsburgh 8, Pa., Rep. N. R. Chillingworth.

Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Pa., Rep. W. H. Sisson, Industry Mgr.

Morse Boulger Destructor Co., Sewage & Waste Div., 205 E. 42nd St., New York 17, N. Y.

Mueller Co., 512 W. Cerro Gordo St., Decatur, Ill., Rep. R. H. Morris.

National Water Main Cleaning Co., 50 Church St., New York, N. Y., Rep. J. A. Frank, Pres.

Nichols Eng. & Research Corp., 60 Wall Tower, New York 5, N. Y., Rep. R. W. Rowen.

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill., Rep. L. E. Rein.

Pittsburgh-Des Moines Co., Neville Island Branch, Pittsburgh 25, Pa., Rep. L. E. O'Leary.

Pittsburgh Pipe Cleaner Co. of N. Y., Inc., 990 Broad St., Newark, N. J., Rep. Kyle I. Robinson, Pres.

Preload Co., Inc., 211 E. 37th St., New York 16, N. Y., Rep. E. H. Thwaits, Vice-Pres.

Price Brothers Co., 1932 E. Monument Ave., P. O. Box 825, Dayton 1, Ohio, Rep. Harry S. Price, Jr.

Public Works Magazine, 310 E. 45th St., New York, N. Y., Rep. W. A. Hardenbergh.

Rockwell Mfg. Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa., Rep. J. F. O'Grady.

Royer Foundry & Machine Co., 158 Pringle St., Kingston, Pa., Rep. S. B. Davies, Pres.

Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa., Rep. Everett M. Jones, Sales Mgr.

Smith Mfg. Co., A. P., 545 N. Arlington Ave., E. Orange, N. J., Rep. W. P. Baerenrodt.

Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif., Rep. F. V. Long, Pres.

Walker Process Equipment, Inc., Aurora, Ill., Rep. J. D. Walker, Pres.

Wallace & Tiernan Co., Inc., 25 Main St., Belleville 9, N. J., Rep. T. T. Quigley.

Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y., Rep. John F. Benjamin, Vice-Pres. in Charge of Sales.

Wastes Engineering, 24 W. 40th St., New York 18, N. Y., Rep. Karl M. Mann.

Water & Sewage Works, 185 N. Wabash Ave., Chicago 1, Ill., Rep. E. S. Gillette.

Westinghouse Electric Corp., P. O. Box 146, Pittsburgh 30, Pa., Rep. William L. James.

Wood Co., R. D., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa., Rep. Theodore W. Wood.

Worthington Corp., Harrison, N. J., Rep. C. K. Hood, Vice-Pres.

Yeomans Brothers Co., 1999 N. Ruby St., Melrose Park, Ill., Rep. Charles Yeomans, Pres.

SUPPLEMENTAL MEMBERSHIP DIRECTORY *

The last full membership listing, published in the March 1954 issue of THIS JOURNAL, gave the membership roster of Member Associations as of December 31, 1953. This supplemental listing, therefore, includes only the names and addresses of those who have been added to that previous listing as new or reinstated members during 1954 and therefore were not included in the main biennial listing.

Abell, DeWitt S., Dist. San. Engr., State Dept. of Health, 601 Hotel Jamestown Bldg., Jamestown, N. Y. (N.Y.)

Acks, William F., Plt. Mgr., Bechtel-McLaughlin, Inc., P. O. Box 948, Sandusky, Ohio (Ohio)

Adams, Archie C., Dist. Engr., Wallace & Tiernan Co., Inc., 1408½ 15th St., Huntington, W. Va. (W. Va.)

Adams, Harry G., Plt. Engr., General Electric Co., 32 Brooks Ave., Burlington, Vt. (N.Y.)

Addenbrook, J. Robert, see Addenbrook's Sons, Inc., J. U.

Addenbrook's Sons, Inc., J. U., Att: J. Robert Addenbrook, Sec., 119 W. 25th St., Norfolk 10, Va. (Corp. Va.)

Adee, L. E., Continental Oil Co., P. O. Box 2103, Billings, Mont. (Mont.)

Adiconis, Michael, Supt., Sewer Dept., Madeira Beach, Fla. (Fla.)

Airkem Chicago, Inc., Att: Eugene G. Erwin, 6735 N. Honore St., Chicago 26, Ill. (Corp. Cen. St.)

Akers, Ward L., San. Engr., State Bd. of Health, 121 Fourth Ave., Rock Island, Ill. (Cen. St.)

Alberts, Richard D., Designer, Ammann & Whitney, 2168A S. 25th St., Milwaukee, Wis. (Cen. St.)

Albertson, Murray G., Sales Engr., Dorr Co., 136 Sylvan Knoll Rd., Stamford, Conn. (N.Y.)

Albright, Richard O., 4525 Marcy Lane, Apt. 250, Indianapolis, Ind. (Cen. St.)

Alford, M. D., Supt., Mun. Sewerage System, Hot Springs, Ark. (Ark.)

Aliberti, Henry J., City Engr., 103 Wilbour St., Lewiston, Maine (New Eng.)

Allen, John, Supt. of Sewers, City Bldg., Wichita, Kans. (Kans.)

Allen, Ocie C., Design Engr., Freese & Nichols, 407 Danciger Bldg., Ft. Worth, Tex. (Tex.)

Allen, R. E., 14519 Kenny St., Houston 15, Tex. (Tex.)

Alsop, John R., Jr. San. Engr., State Dept. of Pub. Health, 135 N. Oakland Ave., Pasadena, Calif. (Calif.)

Alspaugh, Thomas A., Chem., Cone Mills Lab., 1311-D Walker Ave., Greensboro, N. C. (N.C.)

Alta, Town of, Att: C. F. Sangstron, Clerk, Alta, Iowa (Iowa)

American Viscose Corp., Att: L. H. Pownall, Roanoke 7, Va. (Corp. Va.)

Amidon, Willard C., Supt. of Sewerage, Village Hall, Sparta, Mich. (Mich.)

Amos, Jack R., Stud., Purdue Univ., Ross Ade Dr., Bldg. 6, Apt. 5, West Lafayette, Ind. (Cen. St.)

Anderson, Glade, Sales Engr., Pacific States Cast Iron Pipe Co., 6399 Wilshire Blvd., Los Angeles, Calif. (Calif.)

Anderson, H. P., Supt., Sewage Plt., 575 Oak St., Mountain View, Calif. (Calif.)

Anderson, James C., Chief Oper., P. O. Box 213, Woodland, Calif. (Calif.)

Anderson, Robert, Sr. Oper., 3437 Lincoln Ave., Dearborn, Mich. (Mich.)

Anderson, Thomas P., Engr., Div. of of San. Eng., State Bd. of Health, Columbia, S. C. (S.C.)

Andolino, Michael D., Jr., Acting Supt., Disp. Plt., 1239 Sunnyside Dr., Fairlawn, N. J. (N.J.)

Andrews, C. C., City Engr., Anderson, S. C. (S.C.)

Andrews, W. F., Sales Mgr., General Filtration & Eng. Ltd., 1546 Avenue Rd., Toronto, Ont., Can. (Can.)

Angley, E. A., Supt., Sewage Trt. Plt., 109 E. Michigan Ave., Marshall, Mich. (Mich.)

Anschutz, Charles F., Oper., Sewage Plt., 509 First Ave., E., Rock Rapids, Iowa (Iowa)

Anthony, Arthur C., Civ. & San. Engr., Levitt & Sons, Inc., 45 Glenwood Lane, Levittown, Pa. (Pa.)

Arrowhead Lime & Chem. Co., Sales Div., U. S. Lime Products Corp., Att: Carroll Stephens, 57 Post St., San Francisco 4, Calif. (Corp. Calif.)

Arthur, Lawrence B., Supt., Sewage Plt., 429 N. Elm St., Lincoln, Ill. (Cen. St.)

Art Metal Works, Inc. (Pa.), Att: J. H. Stoner, Plt. Mgr., 250 Harris St., E. Stroudsburg, Pa. (Corp. Pa.)

Associated Industries of N. Y. State, Inc., Att: J. R. Shaw, 1 Elk St., Albany 7, N. Y. (Corp. N.Y.)

Atkins, Chester S., Supt. of Water, Box 152, Pasadena, Tex. (Tex.)

Attwell, Walter G., Head of Sanitation Dept., 520 E. Palm Ave., Burbank, Calif. (Calif.)

Auchter, M. J., see Charmin Paper Mills, Inc.

Aulenbach, Donald B., Res. Fellow, Dept. of Sanitation, Rutgers Univ., 441 River Rd., Dover, Del. (N.J.)

Austin, B. R., Supt., Water & Sewage Plt., Clinton, S. C. (S.C.)

Austin, E., Joanna Cotton Mills Co., Joanna, S. C. (S.C.)

Bach, R. S., Sales Engr., General Filtration & Eng. Ltd., 1546 Avenue Rd., Toronto, Ont., Can. (Can.)

Backflow Eng. & Equip. Co., Att: Leonard L. Snyder, Chief Engr., 5725 Alcoa Ave., Los Angeles 11, Calif. (Corp. Calif.)

Bague, Francisco R., P. R. Aqueduct & Sewer Serv., Guayama, P. R. (P.R.)

Baigas, Joseph F., Jr., Engr., Water & Effluent Staff, Celanese Corp. of America, Textile Div., Charlotte, N. C. (N.C.)

Bailey, J. F., Sec. & Gen. Mgr., Tex. Vitrified Pipe Co., Mineral Wells, Tex. (Tex.)

Baird, Floyd E., Mfr. Agent, Engineered Products Co., 1401 Peachtree St., N.E., Rm. 401, Atlanta, Ga. (Ga.)

Bankson, E. Edwin, Cons. Engr., Ellis E. Bankson & Sons, 1116 Berger Bldg., Pittsburgh 19, Pa. (Pa.)

Barber, B. P., Barber, Keels & Assoc., Inc., 1418 Marion St., Columbia, S. C. (S.C.)

Bare, Ben K., Cons. Engr., Burgess & Niple, 2015 W. Fifth Ave., Columbus 12, Ohio (Ohio)

Barko, John M., Gen. Foreman, Finishing Dept., Daystrom Instrument Div., Archbald, Pa. (Pa.)

Barlow, Jesse H., Commr. of Sanitation, City Hall, Grand Island, Nebr. (Nebr.)

Barnes, Chester W., Foreman, Sewage Trt. Plt., Ore. Tech. Inst., 4427 Bisbee St., Klamath Falls, Ore. (Pac. N.W.)

Barnes, Thomas C., Supt., Sewage Trt. Plt., 4430 Bisbee St., Klamath Falls, Ore. (Pac. N.W.)

Barnes, Thomas J., Councilman of Sanitation, Box 258, North Beach, Md. (Md.-Del.)

Baron, George C., Design Engr., Harold S. Prescott, Cons. Engr., 594 Main St., Placerville, Calif. (Calif.)

Barth, T. S., 7236 Appleton St., Houston 22, Tex. (Tex.)

Bascaran, Jose N., P. R. Aqueduct & Sewer Serv., Box 2932, San Juan, P. R. (P.R.)

Bassall, V. A., City Mgr., Municipal Bldg., Junction City, Kans. (Kans.)

Baudoin, J. B., Chief Oper., Sewage Trt. Plt., 1115 St. Johns St., Lafayette, La. (La.)

Bauer, Robert O., Inspection Engr., Water Dept., 4826 N. 13th St., Philadelphia 41, Pa. (Pa.)

Bauerlein, Charles B., Field Engr., Fischer & Porter Co., 29 Bala Ave., Bala Cynwyd, Pa. (Pa.)

* Member Association affiliation shown in parentheses.

Beach, Robert W., Chairman, Bd. of Commr., Lake City Sewer Dist., 4262 E. 125th St., Seattle, Wash. (Pac. N.W.)

Beail, Earl, Supt., Sewage Trt. Plt., P. O. Box 218, Coos Bay, Ore. (Pac. N.W.)

Beall, Roger W., Supt. of Water Dept., 503 Planter St., Bainbridge, Ga. (Ga.)

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Walker, George L., Mgr., N. Y. Dist., Simplex Valve & Meter Co., 330 W. 42nd St., Rm. 700, New York 36, N. Y. (N.Y.)

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Wallace, George C., Metcalf & Eddy, 1300 Statler Bldg., Boston 16, Mass. (Calif.)

Wallace, W. A., Sr., Pres., Wallace Equip. Co., Foot W. Adams St., Jacksonville, Fla. (Fla.)

Walling, I. W., Dist. Chem., U. S. Dept. of Interior Water Resources Lab., 2520 Marconi Ave., Sacramento 21, Calif. (Calif.)

Wallis, L. E., Supt., Water & Light Dept., Elberton, Ga. (Ga.)

Walsh, Robert J., Vice-Pres., D. L. Maher Co., 38B Brattle St., Cambridge, Mass. (New Eng.)

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Warner Co., Cedar Hollow Lab., Devault, Pa. (Corp. Pa.)

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Warring, M. A., Supt. of Streets, 1162 N. 3rd St., Woodburn, Ore. (Pac. N.W.)

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Webster, Claude D., Commr., Lake City Sewer Dist., 2628 E. 138th Pl., Seattle, Wash. (Pac. N.W.)

Weeks, R. Kenneth, Partner, Causey & Weeks, Engr., P. O. Box 10038, 5205½ E. Sewells Point Rd., Norfolk 13, Va. (Va.)

Weems, W. J., Mgr., Water & Sewer Systems, 4th & Texas Ave., Texarkana, Ark.-Tex. (Ark.)

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Weinberg, Robert, Prod. Mgr., Consumer-Farmer Milk Co-op., Inc., 35-30 36th St., Long Island City, N. Y. (N.J.)

Welden, Ray W., Vice-Pres., Eng. & Res., Great Northern Paper Co., 6 State St., Bangor, Maine (New Eng.)

Wellings, John L., Machinists Mate 2/c, Naval Air Sta., Dept. of Pub. Wks., Willow Grove, Pa. (Pa.)

Wells, William T., City Mgr., Waynesboro, Va. (Va.)

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White, Fred C., Salesman, James Maskell, 1808 Oak Hill Lane, Richmond, Va. (N.J.)

White, Ken R., Cons. Eng., 941 E. 17th Ave., Denver, Colo. (Rky. Mtn.)

White, William E., Chief Design Engr., Pub. Wks. Dept., City Hall, Rm. 402, Houston, Tex. (Tex.)

Whitels, W. E., Area Supvr., Hercules Powder Co., Burlington, N. J. (N.J.)

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Whitman, Ezra B., Cons. Engr., Whitman, Requardt & Assoc., 1304 St. Paul St., Baltimore 2, Md. (Md.-Del.)

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Wilson, London, 5213 Carmen St., Houston 21, Tex. (Tex.)

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Winters, Rudy, Commr., Water & Sewer, Rushville, Nebr. (Nebr.)

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Young, John T., Cons., Ariz. Concrete Pipe Assn., P. O. Box 2830, Phoenix, Ariz. (Calif.)

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Zabban, Walter, Chem. Engr., The Chester Engr., 210 E. Park Way, Pittsburgh 12, Pa. (Pa.)

Zee, Dr. H. W. D., 76 Roerstraat, Amsterdam 2, Holland (ISP)

Zeidlhack, Felix S., Partner, John W. Cunningham & Assoc., 1112 Portland Trust Bldg., Portland 4, Ore. (Pac. N.W.)

Zeigler, James A., Flavet III, Apt. 211-S, Gainesville, Fla. (Fla.)

Zimmerman, Albert F., Dir., Quality Control Lab., Pine Rd., Fox Chase, Philadelphia 11, Pa. (Pa.)

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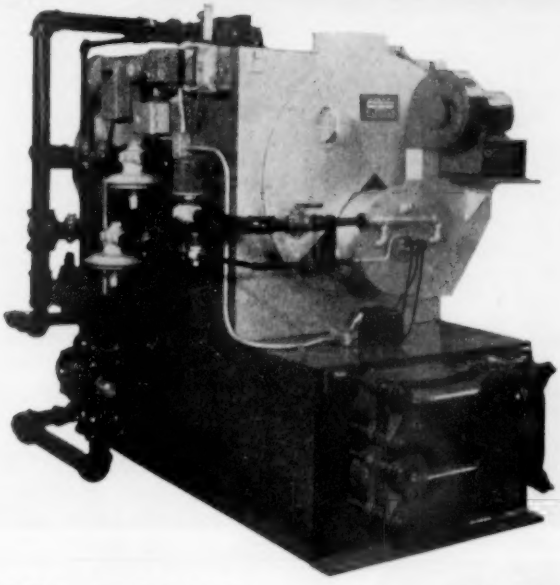
HEATX UNIT

Digester Heat Exchanger



370,000 BTU/hr. HEATX for installation at Villa Park, Illinois. Burner automatically utilizes sewage gas or natural gas separately or in combination. A pre-ignition purge cycle clears the combustion chamber of any fuel accumulation before starting or between fuel switch-over.

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HIGH RATE OF HEAT TRANSFER
NO SLUDGE ADHESION

The HEATX is designed to allow absolute and independent control over each function of sludge heating; namely, heating of jacket water, control of temperature and flow of jacket water and control of digester temperature and rate of turnover.

The HEATX is offered as either a separate exchanger, for use with existing standard boilers or as a package unit complete with a Walker Process boiler and burner. Boilers are designed to burn sewage gas, sewage gas and oil or sewage gas and natural gas.

The concentric tube type exchanger is equipped with special removable end castings arranged to prevent contamination of the heating water by material circulated through the sludge tubes.

Write for Bulletin 24S82.

Engineering and manufacturing a complete line of water, waste and sewage treatment equipment.

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WALKER PROCESS EQUIPMENT INC.
Factory — Engineering Offices — Laboratories
Aurora, Illinois

Proceedings of Member Associations

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1954 Spring Meeting of the New York Sewage and Industrial Wastes Association was held at the Hotel Syracuse, Syracuse, N. Y., on June 14–15, 1954.

In addition to an inspection trip to the city's Ley Creek sewage treatment plant, technical papers were presented as follows:

"The Current Status of the Pollution Problem in Onondaga Lake," by A. F. Dappert, Executive Secretary, N. Y. State Water Pollution Control Board, Albany.

"The Treatment of Machine Shop and Foundry Wastes," by C. W. Hathaway and R. E. Harvie, Metallurgical Dept., Chevrolet Motor Div., General Motors Corp., Detroit, Mich.

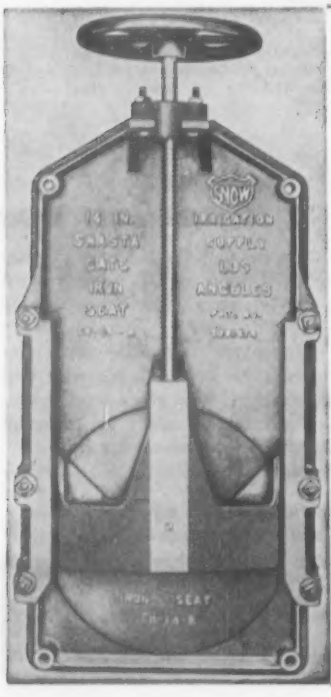
"A County Public Health Engineer's Approach to Problems Involving Sewerage and Sewage Treatment," by M. J. Stankewich, Chief, Bureau of Water and Sewage Control, Erie County Health Dept., Buffalo.

"Elutriation Difficulties at the Bay Park Sewage Treatment Works," by Anton E. Sparr, Superintendent, Nassau County Bay Park Sewage Treatment Plant, East Rockaway.

"A Review of Methods for the Determination of Cyanides in Sewage," by D. F. Krawczyk, Associate Sanitary Chemist, Buffalo Sewer Authority.

"The Development of a Program for Abatement of Pollution of Chau-

(*Continued on page 112a*)



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for
SEWAGE TREATMENT PLANTS

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It's simple chemistry...
TNEMEC PRIMERS KILL RUST!
From acid (rust) condition to alkaline (NON-RUST) condition in one easy step with
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tauqua Lake," by Roland M. Austin, Public Health Engineer, Chautauqua County, Mayville.

"Construction and Maintenance of Industrial Sewers," by Ernest K. Smith, Civil Engineer, Eastman Kodak Co., Rochester.

"Water Conservation and Resulting Waste Control Benefits at Electronics Park," by W. B. Miller, Air Conditioning Engineer, General Electric Co., Syracuse, and V. DeP. Lukas, Sanitary Engineer, General Electric Realty Corp., Schenectady.

"Waste Disposal Problems in a Pharmaceutical Plant," by W. D. Hanlon, Chemical Engineer, Bristol Laboratories, Syracuse.

"Description of the Ley Creek Sewage Treatment Plant," by Uhl T. Mann, Superintendent, Ley Creek Sewage Treatment Plant, Syracuse.

A. J. Fischer, Stamford, Conn., was elected as Federation Director representing the Association, to serve during 1954–7.

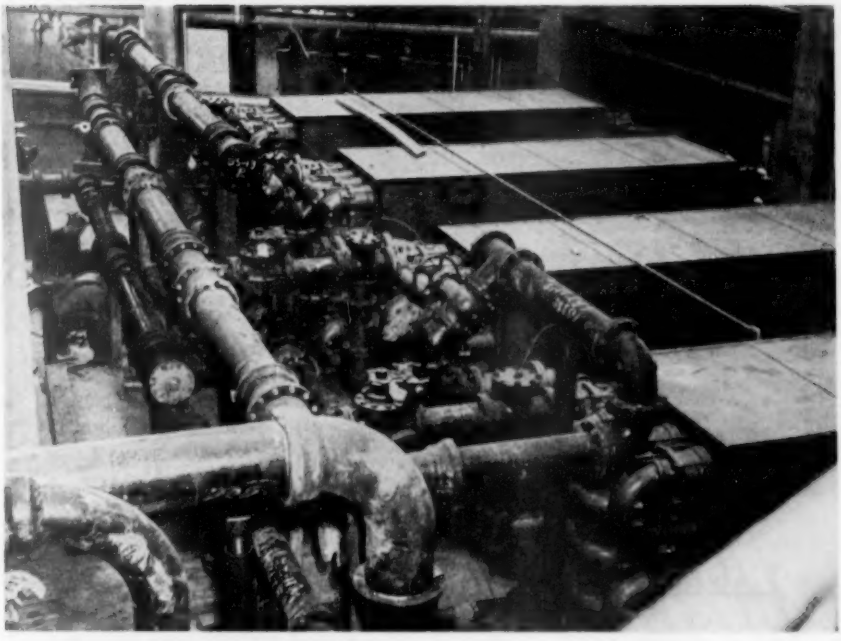
R. C. SWEENEY,
Executive Secretary

PENNSYLVANIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 26th Annual Conference of the Pennsylvania Sewage and Industrial Wastes Association was held at Pennsylvania State University, State College, Pa., on August 25–27, 1954. Some 230 members and guests registered for the meeting.

In addition to a Sewage Operators' Round Table, with a discussion panel comprising J. J. Fitch, Jr., Reading; D. D. Day, Meadville; J. B. Volk, Penn Township; A. E. Fricker, Philadelphia; and E. R. Harding, Sr., Bloomsburg, an Industrial Wastes Symposium on "Plant Changes to Minimize Pollution" included papers by Carl J. Swartz, Chief Chemist, L. F. Grammes and Sons Co., Allentown; Clifford W.

(*Continued on page 114a*)



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For Sewage Treatment Plants

AMERICAN cast iron pipe has the lasting qualities that enables it to survive continued corrosive attack, year after year, and to keep on giving the same dependable, economical service as the day it was installed. It is manufactured under rigid specifications in diameters 2-inch through 48-inch. This pipe is made in specific weights for specific operating conditions. You get the exact pipe your conditions require.

A complete line of standard fittings is available, and our foundry is equipped to make "specials" to order. The above photograph made in a sewage treatment plant in Cleveland, Ohio, illustrates the wide range of our foundry service on pipe and fittings.

In addition to complete foundry facilities, AMERICAN extends the services of its experienced engineering organization for assistance in preparing piping plans and taking off lists of material.

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Population equivalents of 5500 or less, whether for schools, hospitals, resorts, certain trade wastes, small communities or subdivisions.

A visit to one of the many Spiragester installations will reveal a lack of odors and unsightliness.

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Write for Bulletin 135

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Watson, Jr., Sanitary Engineer, Dairymen's League Cooperative Assn., New York, N. Y.; and Bruce W. Dickerson, Sanitary Engineer, Hercules Powder Co., Wilmington, Del.

Air diffusion experiences with Saran tubes were discussed by Stanley E. Kappe, Kappe & Associates, Washington, D. C., and Miles Lamb, Chicago Pump Co., Chicago, Ill.; experiences with ceramic tubes were discussed by Frank C. Roe, Sr., Refractories Division, The Carborundum Co., Perth Amboy, N. J.

Other papers were presented as follows:

"Acceptability of Industrial Wastes into Public Sanitary Sewer Systems from the Operator's Viewpoint," by A. A. Estrada, Vice-President, Albright & Friel, Inc., Philadelphia; George A. Elias, Pennsylvania Department of Health; and Gordon J. Wiest, Technical Director, Warner Co., Philadelphia.

"Plant Maintenance Experiences," by Frank S. Varner, Superintendent, Bureau of Sewage Disposal, Altoona, and King H. Hendrickson, Superintendent, Sewage Treatment Plant, Beaver Falls.

"Full-Scale Dual Disposal Effect on Sewage Treatment," by Morris M. Cohn, Editor, *Wastes Engineering*, New York, N. Y.

"Home Garbage Grinding Economics," by R. Rupert Kountz, Professor of Sanitary Engineering, Pennsylvania State University, State College.

"Administrative Control of Stream Pollution," by C. W. Klassen, Chief Sanitary Engineer, State Dept. of Public Health, Springfield, Ill.

"Operational Digester Problems," by John Yenchko, Pennsylvania Dept. of Health, Wilkes-Barre.

Officers were elected as follows:

President: G. J. Weist, Jenkintown.

(*Continued on page 116a*)

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Gives You Strong, Durable, Economical Sewers

Leading sanitary engineers specify concrete pipe for sewers because it offers:

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5. **ECONOMY.** Moderate first cost plus little or no maintenance expense divided by long years of service equal *low annual cost,* the real measure of pipe line economy.

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2nd Vice-President: G. A. Elias, Philadelphia.
Secretary-Treasurer: B. S. Bush, Wilkes-Barre.

BERNARD S. BUSH,
Secretary-Treasurer

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 26th Annual Convention of the North Dakota Water and Sewage Works Conference was held September 22–24, 1954 at the Dacotah Hotel, Grand Forks, N. Dak. A total of 123 persons registered, including 17 ladies.

Papers presented included the following:

"Power Transmission," by F. W. Stuve, North Dakota Agricultural College, Fargo.

"Safety," by Paul Drew, Safety Department, Workmen's Compensation Bureau.

"Lubrication Schedules for Plant Maintenance," by E. A. Tschida, Water Works Superintendent, Dickinson.

"Public Improvements," by George J. Toman, Consulting Engineer, Mandan.

The Federation's Arthur Sidney Bedell Award was presented to John Kleven.

Officers elected to serve during 1954–5 were as follows:

President: P. Hays, Minot.
Vice-President: E. Ostlie, Grand Forks.
Secretary-Treasurer: J. H. Svore, Bismarck.

JEROME H. SVORE,
Secretary-Treasurer

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 20th Annual Meeting of the South Dakota Water and Sewage Works Conference was held in Mitchell, S. Dak., September 28–30, 1954. The total registration was 112, plus 22 ladies.

Papers of interest to wastes treatment personnel were as follows:

"Maintenance of Sewage Collection System," by F. S. Dixon, Municipal Equipment Co., Hopkins, Minn.

"Mitchell Sewage Treatment Plant," by Marvin Heck, City Engineer, Mitchell.

"Lagoon Performance," by Marvin Allum, Biologist, Division of Sanitary Engineering, South Dakota State Board of Health.

Inspection trips were made to the new Mitchell water treatment plant, the sewage treatment works, and the Geo. A. Hormel Packing Co.

At the business meeting, a program of voluntary certification of South Dakota water and sewage works operators was adopted. Officers elected for 1954–5 were as follows:

(*Continued on page 118a*)

A frank appraisal of certain "new developments" in accelerated sludge digestion

As responsible members of the wastes engineering profession, we feel it is time to set the record straight regarding recently made claims for accelerated sludge digestion.

A manufacturer has claimed spectacular results from experiments with a new sludge digestion process. On the basis of publicized tests conducted at Columbus, Ohio, he claims the process *triples* the rate of digestion and thereby reduces the required digester capacity in any one plant. The manufacturer's recent advertisements contain this statement:

> "The (process) applied to one 70' tank at the Columbus plant digested 3.38 times the quantity of sludge solids digested in a similar tank in *parallel operation* not using the process."

The claims are contradicted—This statement is a misrepresentation of the facts, as indicated by another report of the actual test program in a paper presented by this manufacturer's representative at the Missouri Water and Sewage Works Conference on September 27, 1954:

> "During the 10-month test period, about 20% of the total plant sludge was directed to the digester using the new process, while the remaining 80% was directed to 14 other units. The tank using the new process was operating at a loading rate of about 3.35 times the loading rate of the conventional digesters."

Since no attempt was made to increase the load in any other tank under similar conditions, *it was not a parallel operation and there is no legitimate basis for comparison.* It is merely the comparison of one tank fed at a high rate with other tanks being fed what is left of the available solids. There is no reason to believe that the conventional digesters might not have operated at this same increased loading.

Misleading claims can delay important projects—This misrepresentation of the facts, and the claims that *any* plant need be provided with only one-third of the digestion capacity normally recommended by State Boards of Health do not take into consideration the various factors of the individual designs which might include the method of disposal of the digested sludge, the necessity of sludge storage and of securing separation of digester liquor. That these claims may be upsetting to the entire industry is pointed out by the experience of one prominent consulting engineer. Upon submitting a report for necessary additions to an existing plant, the engineer was challenged by city officials who had heard the above claims and concluded that the existing digestion capacity was more than adequate. The project was delayed for more than a year until this consulting engineer finally found it necessary to justify the need for additional digestion capacity by actual plant demonstrations.

Sewage treatment processes of theoretical value cannot be applied indiscriminately to any and all plants. A competent engineer knows that every plant is different in terms of wastes to be treated, facilities, budget limitations and personnel. It is the consulting engineer's job to study these conditions and design the most efficient and *practical* plant for that community.

This is our policy—PFT will continue to advocate the use of established design criteria for digestion capacity as formulated by consulting engineers and State Boards of Health. We feel that these criteria are developed to take into consideration practical plant operating procedures and future requirements.

PFT works constantly for progress—PFT has contributed many advanced methods and controls for improving the sludge digestion process—the *PFT Floating Cover*, the *PFT External Heater*, the *PFT Supernatant Liquor Controls*, and the *PFT Pearth Gas Recirculation System*, among others.

But PFT never has and never will claim operational features for its equipment on the basis of inadequate or inconclusive tests.

The second in a series of PFT policy statements regarding sludge digestion criteria and practices.

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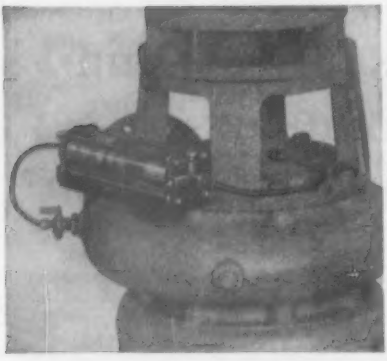

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CANADIAN INSTITUTE ON SEWAGE AND SANITATION

The 21st Annual Convention of the Canadian Institute on Sewage and Sanitation was held at the Windsor Hotel, Montreal, Que., on October 25–27, 1954. A new attendance record was set by the registration of 501 members and guests plus 140 ladies.

Among the technical papers presented were the following:

"Safety Requirements in Sewer Trenches," a guided discussion led by G. H. Baker, Engineer, North York Township, Ont.

"Liquid Raw Sludge as Fertilizer," by W. M. Veitch, Consulting Engineer, London, Ont.

"Dewatering of Digested Sludge by Lagooning," by N. S. Bubbis, General Manager, Greater Winnipeg Sanitary District, Winnipeg, Man.

"Mechanical Drying for Fertilizer," by R. K. Kilborn, Consulting Engineer, Toronto, Ont.

"Incineration of Sludge," by L. B. Allan, Commissioner of Works, Metropolitan Toronto, Ont.

"Stream Pollution—A National Problem," by Douglas A. Shand, Chairman, Public Service Commission, Pointe-Claire, P. Q.

"Refuse Collection and Street Cleaning," A guided discussion led by L. L'Allier, Montreal, P. Q.

"Incineration of Refuse," by A. J. Deslauriers, City Engineer, Lachine, P. Q.

"Sanitary Land Fill," by G. H. Richards, City Engineer, Brantford, Ont.

"Digestion of Refuse for Land Supplement," by A. E. Berry, Ontario Department of Health, Toronto, Ont.

"Disposal of Refuse on the Premises," by R. J. Desmarais, City Engineer, Windsor, Ont.

"Can the Costs of Sewage Works Be Reduced?" a guided discussion led by L. B. Allan, Toronto, Ont.

"British Practice in the Control of Industrial Wastes," by G. T. G. Scott, Consulting Engineer, Toronto, Ont.

"Instrumentation of Sewage Treatment Works," by J. F. MacLaren, Consulting Engineer, Toronto, Ont.

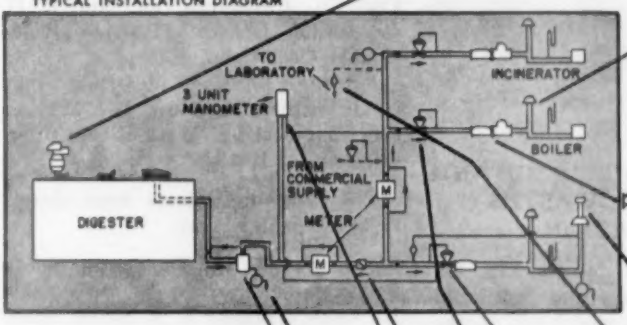
"Lagooning as a Sewage Treatment Process," by J. G. Schaeffer, Director, Division of Sanitation, Province of Saskatchewan, Regina, Sask.

"Sewage Treatment Plant Supervision," by L. F. Robertson, Engineering Assistant in Charge of Sewage Disposal, London, Ont.

At the business meeting, the Institute's constitution was amended to raise the dues from $4 to $7 to establish a full-time Assistant Secretary to administer both the Institute and the

(*Continued on page 120a*)

TYPICAL INSTALLATION DIAGRAM



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Vice-President: C. G. R. Armstrong, Windsor, Ont.
Secretary-Treasurer: A. E. Berry, Toronto.

A. E. Berry,
Secretary-Treasurer

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 8th Annual Meeting of the West Virginia Sewage and Industrial Wastes Association was held at the Prichard Hotel, Huntington, W. Va., on November 9–10, 1954, with part of the program being participated in jointly with the West Virginia Section, AWWA. There was a record all-time high registration of 245, including ladies, for both organizations, with 191 registering for the Association meeting.

Among the technical papers presented were the following:

"Koppers New Dephenolizing Plant at Follansbee, W. Va.," by H. A. Kjellman, Process Engineering Section, Tar Products Div., Koppers Co., Inc., Pittsburgh, Pa.

"Resume of Waste Treatment by Carbide (B.O.D. Determination on Pure Chemicals)," by E. J. Mills, Jr., and V. T. Stack, Jr., Carbide and Carbon Chemicals Co., S. Charleston, W. Va.

"Notes on Industrial Wastes Trickling Filters," by Harry W. Pitts, Jr., and Louis A. Tucci, Sanitary Engineers, Organic Chemical Div., American Cyanamid Co., Bound Brook, N. J.

"Sewage—The Municipal Problem," by a panel comprising representatives of industry, municipalities, regulatory bodies, legal counsel, and financing interests.

"Coal Washery Wastes," a symposium by L. Gillenwater, Assistant Engineer, West Virginia State Water Commission; H. F. Hebley, Research Consultant, Pittsburgh Consolidated Coal Co., Pittsburgh, Pa.; and E. H. Greenwald, General Manager, Boone County Coal Corp., Sharples.

"Sewer Jointing Materials," by G. O. Fortney, Engineer, Div. of Sanitary Engineering, West Virginia Department of Health.

The following officers were elected for the ensuing year:

President: O. C. Thompson, South Charleston.
1st Vice-President: T. K. Bruce, Bluefield.
2nd Vice-President: J. W. Lester, Charleston.
FSIWA Director: H. K. Gidley, Charleston.
Secretary-Treasurer: G. O. Fortney, Charleston.

The Arthur Sidney Bedell Award was presented to Professor Henry Withers Speiden, of West Virginia University.

Glen O. Fortney,
Secretary-Treasurer

SOUTH CAROLINA WATER AND SEWAGE WORKS ASSOCIATION

On September 30, 1954, the South Carolina Water and Sewage Works Association held its 1954 Annual Meeting at Heise's Pond near Columbia, S. C., in conjunction with a barbecue dinner.

Officers elected to serve during 1954–5 were as follows:

President: J. D. Spence, Greenville.
Vice-President: J. D. Leslie, Fort Mill.
Secretary-Treasurer: T. A. Kolb, Columbia.

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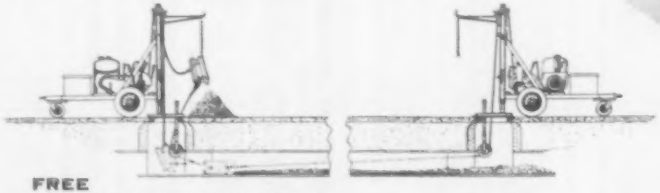

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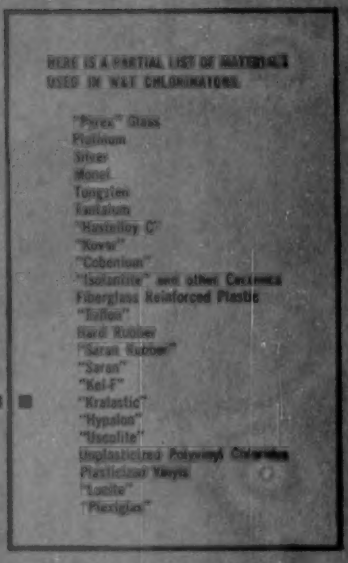

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